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MINUTES OF PROCEEDINGS

OF

THE INSTITUTION OF CIVIL ENGINEERS.

VIEW OF THE EDDYSTONE FROM THE NORTH EAST, 1882. *See page 30.*

MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. LXXV.

EDITED BY

JAMES FORREST, Assoc. Inst. C.E., Secretary.

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CONTENTS.

SECT. I.—MINUTES OF PROCEEDINGS.

13 *November*, 1883.

20 *November*, 1883.

27 *November*, 1883.

4 *December*, 1883.

18 *December*, 1883.

SECT. II.—OTHER SELECTED PAPERS.

SECT. III.—ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

ERRATA.

Vol. lxxiii., p. 434, second paragraph, *for* "kilograms" *substitute* "hectolitres" in all cases.
" lxxiv., p. 241, line 15, *for* "unexpected" *read* "unexpended."
" " " " " 23, reference to the plate to be omitted here, and inserted at third line from the bottom, after the word "each."
" " " 245 " 2, *for* "assist" *read* "resist."
" " " 298 " 12, *for* "was daily deflected at an angle of about 10″ from the vertical axis," *read* "turned daily through an angle of 10″ about its vertical axis."
" " " 299 " 21, *for* "Munich" *read* "M. Gladbach."
" " " 383 " 10, in the numerator of the second member of the equation the second letter should be E instead of R.
" " " 386 " 17, *after* "take" *add* "values differing from."

THE
INSTITUTION
OF
CIVIL ENGINEERS.

SESSION 1883-84.—PART I.

SECT. I.—MINUTES OF PROCEEDINGS.

13 November, 1883.

JAMES BRUNLEES, F.R.S.E., President,
in the Chair.

Mr. BRUNLEES, President, said it was pleasing to see at the opening meeting so large a gathering, which he hoped was only an indication of what might be expected throughout the Session. The members were aware that Mr. Bruce, Vice-President, had recently attended the opening of the Northern Pacific Railroad, and was now prepared to give an account of his visit.

ADDRESS.

"The Northern Pacific Railroad."

By GEORGE BARCLAY BRUCE, V.P. Inst. C.E.

DURING the recess it had been his privilege to visit the United States of America as the representative of this Institution, on the occasion of the completion of a large and important line of railroad, and the Council considered it desirable that some notice should be taken of this upon the evening of the first Ordinary Meeting of the Session. He would gladly have shrunk from the duty, but it was felt to be due to the generous hospitality with which the representative of the Institution had been received on the other side of the Atlantic, that it should not be passed over in silence.

The circumstances of the case were these. The President, Mr. Henry Villard, and the Directors of the Northern Pacific Railroad, invited, through the Secretary of State for Foreign Affairs in this country, Earl Granville, the Institution of Civil Engineers, as representing the civil engineering interests of Great Britain, to be present through their representative on the occasion of the completion of that road, forming the most northerly connecting line between the Atlantic and the Pacific Oceans in the United States of America. Unfortunately their esteemed President was unable, through other engagements, to go, and it fell to his lot, as one of the Vice-Presidents, to take that place.

Invitations were also given, through the same channel, to important departments of the Government of this country, and he had the pleasure of finding himself in the company of the representatives of the Board of Trade, in the persons of Mr. John Holms, M.P., and of General Hutchinson; Mr. Ebden represented the Colonial Office; Professor Bryce, the Foreign Office ; Sir William Gurdon, the Treasury; and its chairman, Mr. Norwood, one of the members for Hull, the Chamber of Commerce of the City of London. Two distinguished judges in her Majesty's Courts, Members of the Privy Council, and Members of Parliament, also went from this country as the guests of the Northern Pacific Railroad Company. So far-reaching was the hospitality and energy of the Railroad Company that, from the time of leaving Great Britain, all through the journey to the Pacific and back again to this country, they remained as guests of the Company. A still larger number of persons from Germany were summoned to travel over the new line to join in the festivities accompanying the opening, and to form some opinion of the enormous tract of country through which it passes. There were, of course, numerous Americans from different parts of the States who took part in this great trip.

It was probably the largest gathering from the most distant parts of the earth, that was ever summoned to assist in the rejoicings which naturally accompany the completion of so important an enterprise.

The Northern Pacific Railroad was based upon a concession from the Government, the Company making the road, and the Government undertaking to give them 25,000 acres of land per mile of line constructed. The land was given in alternate sections, the Government holding one block, and the Company the next. This might be considered a large grant; but it was evidently a wise policy to bestow it, inasmuch as the country was thereby opened up, the land became a source of wealth and gave life to a great number of people, whereas without the railroad it was worthless to anybody.

The main line of this railroad might be said to begin at Lake

Superior, and it passed through the States of Wisconsin, Minnesota, Dacota, Montana, Idaho, Washington, and Oregon, terminating at the city of Portland in Oregon; or perhaps it might be more properly described as turning off there, and proceeding north to Puget Sound and terminating at Seattle situated on that beautiful inland sea. Turning also down south from Portland, it formed a connection with the railroad leading to San Francisco. The line lay mainly between 46° and 47° north latitude, being about 200 miles south from the boundary between Canada and the United States, and about 300 miles south of the parallel line—the Canadian Pacific Railway.

The distance between the termini at Lake Superior and Puget Sound was about 2,000 miles. There was besides a branch from the main line at Brainerd to St. Paul on the Mississippi of about 140 miles. This would more strictly be the main line, than the part communicating with Lake Superior, inasmuch as the railroad to St. Paul would be the line from which all the traffic from the Northern Pacific towns would travel to Chicago and the eastern ports. A number of branches, also under construction, would bring up the total length to nearly 2,500 miles.

There were other routes across the continent, all of which, however various their course, impinged upon San Francisco. The country through which the line passed near Lake Superior was for 100 miles covered by forest, and the district from St. Paul to Brainerd was also pretty well wooded, but it was to a considerable extent cleared land, with thriving villages and farms along the line. Farther westward, between the Mississippi and the Red River, the country was to a large extent wooded, and interspersed with small lakes, which made it very beautiful and pleasant. Here, too, the land was becoming rapidly settled. Approaching the Red River they came to the great rolling prairies, and it was the first view they had of that style of country. All that region was splendid wheat-land, laid out in enormous farms. The country was becoming settled, and the produce from it was very large. The same character of prairie-land, gradually coming into cultivation, extended over a stretch of 200 miles more to the Missouri River at Bismarck. For about 100 miles beyond this point the land was of pretty much the same character, but it was apparently not so good as to the west of the Missouri River. Farther west the greater part of the land was not suited for raising grain, but it was admirable for the rearing of cattle. He had some conversation on a railroad platform at Glendive with a man engaged in cattle-rearing, who told him that of all honest trades it was that out of which most money could be made. It was not often that a man confessed that his own trade was very lucrative. He explained the matter by saying that he paid nothing for the rent of his land, it being Government land, and that he sent his cattle anywhere, that they needed no shelter during the winter, and no food other than what they could pick up for themselves, so that there was no expense save the cost of a few cowboys when the time came for sending the cattle to market. Farther west still they came to the Rocky Mountains, and into a well-timbered country. Livingstone, Helena, and Bozeman, are in the mining districts, producing large quantities of silver and copper, and here some of the valleys were well cultivated. Bozeman was a very spirited and rising place. Coming down towards the Pacific they reached a splendidly timbered country, where the amount of the lumber trade carried on was enormous. In Walla Walla and the neighbourhood the land was suited for raising wheat, and it was expected to send away 150,000 tons of wheat during this season, taken from an area of 50-miles radius. Altogether, although the country passed through was on the whole valuable, a good deal of the land was inferior and unproductive.

As to the engineering of the line, in America the wise course was adopted of making a line cheaply at first. In a wilderness or desert where there were no habitations, with this object almost all the bridges, at all events the larger ones, were constructed of timber. It was usual to have trussed spans of about 150 feet. The bridge over the Mississippi had three spans of 142 feet. Over the Red River a similar class of work, but more permanent, was being used. At the Missouri River a fine bridge of a different class, about 1,450 feet long, had three spans of 400 feet each, 50 feet clear above the level of the summer floods. They had iron girders, and the iron trussed girders in America were generally much deeper than in England, the 400-feet girders were 50 feet deep. There were also two spans of 113 feet and some shorter spans, and a long length of timber, and iron trestles. The piers were sunk to a very considerable depth. With respect to other timber bridges farther along the line, there were three spans of about 150 feet over the Yellowstone, and some extraordinarily high bridges through the Rocky Mountains, one of them 226 feet high and 860 feet long, over a valley with steep sides. The piers were framed timber piles, and the spans were about 80 feet of ordinary lattice girders. The outer timbers, forming the piers, had a batter of 3 inches to the foot. It was only wide enough for a single line. It was nervous work crossing, being so very narrow, and the depth seemed tremendous; but the Americans were very skilful in their timber work, in their mode of framing it, and in putting it together, and also in erecting it. Another bridge near the last was 112 feet high, and 1,000 feet long, but it was much less formidable to look at. There was a great quantity of timber piling upon the railroad. At a lake where timber piling extended a distance of 2 miles, for about 600 feet the depth was so great that the piles had to be 90 or 100 feet long. A comparatively low bridge was in process of erection as a permanent structure at the Snake River where it joined the Columbia. The navigation had to be kept up through it, and it was therefore made a swing-bridge. The total length was 1,541 feet. The piers and the abutments were all granite. The central pier supported a girder which swung in the usual way. There was an open space on each side of the pier of 138 feet for the passage of vessels. The bridge was not yet completed, and the traffic was conducted by means of a ferry-boat which carried the trains over.

Perhaps the grandest and most imposing feature of the line was where the Columbia River passed through the Cascade Range of mountains. Here the basaltic cliff rose sheer out of the river almost perpendicularly to a height of 450 feet, and the river itself at that place was about 120 feet deep. In constructing the line blasts of enormous proportions were put in, and the face of the hill was blown down into the river below, filling it up to a certain height, and at the same time forming a ledge in the rock for the railroad. In one instance 10 tons of powder were fired at once, which brought down 140,000 cubic yards of rock. The line now lay for a considerable distance along an almost perpendicular hill-side, which, whether when travelling on the railroad, or sailing up the river near it, presented one of the finest scenes that could well be imagined.

The gradients on the line are generally about 1 in 100, except at the Rocky Mountains. In proceeding from Lake Superior to Puget Sound, the mountain land did not, strictly speaking, begin before Livingstone. The steepest gradients on the permanent line over the mountains were about 1 in 45. There were two ranges of the Rocky Mountains, both about 5,800 feet above the sea-level, and through each range a tunnel was being made. A temporary road (to be used till the tunnels are finished) was laid over the summit of the pass in each case, the gradients of which varied from 1 in 21 to 1 in 25. The engines for working over these inclines were about 60 tons weight, having eight wheels coupled with a single Bissell bogie in front.

The permanent way was of the ordinary description, of 4 feet 8½ inches gauge, and the road was well timbered with sleepers. The rails were 56 lbs. to the yard, flat-bottomed, and were of steel. On some parts of the line there was no ballast (a not unusual circumstance in that country), but on the whole it was well ballasted. The ballast was obtained to a large extent from numerous side-ditches and cuttings. When it had consolidated, it would form a thoroughly good road. As to stations and signals, he was afraid that General Hutchinson would be much scandalised at the fact that there was an entire absence of signals; but the plan prevailing in England forty years ago, of depending upon the eyes of the engine-driver to see a train a-head, was adopted. However, the additional advantage of being able to check a train by telegraph was an immense assistance. The stations were nearly all timber, as were the houses in all the towns throughout the district. He had been greatly struck with the skill of the Americans in their organisation of labour. In going into the desert, where there was no facility for getting anything, the people were extremely clever in making their arrangements for carrying everything with them, and having the labour so marked out that every man knew his work. Some of the men were set apart to do the earth-work, others to cut the timber, others to erect it, while others went forward with the commissariat, and everything was done in the most methodical way, as if all the appliances of civilisation were ready to their hands and around them, which reflected great credit upon the ingenuity, perseverance, and skill of the engineers. They had also means of carrying out the earth-work not adopted in this country, and which appeared to him to be very ingenious. To cut out a side-ditch they ploughed the surface of the land. They then went forward with a scoop drawn by two horses, and scooped out the earth without the use of pick, shovel, barrow, or plank, and carried the load to the bank. Several appliances of that kind of which he had taken note were extremely useful in saving labour.

He would next refer to some of the incidents of the journey itself. The directors and officials of American railroads were not content to travel in crowded carriages. Several chairmen and directors of different lines in America came in their own Pullman cars; so that a goodly array of carriages was required for the whole party. The arrangement was that they were all to meet at Chicago. At that place four trains were made up, each having ten Pullman carriages drawn by two locomotives. Everything was done to make them as comfortable as possible. He need not describe the mode of travelling, but journeying as they did day after day and week after week for about a month, living, eating, and sleeping in the cars, they did not get tired. The trip was very enjoyable, they had excellent company amongst themselves and their American friends. They stopped somewhere on the road almost every day, and wherever they halted large numbers of persons came to express their delight at the new state of things. They heard many speeches about the greatness of the country in which they were sojourning, and the importance of the city at which they happened to be. The interest taken in the enterprise was manifested by the fact that at a banquet given on the banks of Lake Minnetonka by the city of St. Paul to the guests and to others, the expedition was honoured by the presence of the President of the United States, as well as by that of General Grant, ex-President, who accompanied the party throughout, and many other distinguished men.

The first places of importance at which they stopped were St. Paul and Minneapolis; cities of about eighty thousand inhabitants each, upon the Mississippi River. Here forty years ago the Red Indians roamed at large. These cities, which were only 7 or 8 miles apart, were very jealous of each other, so that there was a good deal of rivalry between them. The inhabitants regarded the railroad with great interest, because the position was like the neck of a bottle through which all the traffic to the east must pass, and the distributing centre from which it would all be spread towards the west. They had immense mills for grinding flour, and great lumber establishments, which they were able to carry on by the enormous water power at their disposal. The Lord Mayor's show in London was nothing to the imposing processions which met them on their arrival. These were miles in length, and included wagons in which various trades were being carried on; the blacksmith, for instance, with his anvil and bellows, hard at work. Then there was something emblematical of the milling and the lumber trade, and other trades carried on in the country. One feature of the procession amused him greatly. On one of the wagons there was a little box about 3 feet square with pigeon-holes in it, and it was paraded on a wagon by itself as the original post office of the city of Minneapolis forty years ago. It was followed by a wagon on which there was a representation of the post office of the present day, with ladies and gentlemen sorting letters; and all kinds of devices being carried out in connection with the telegraph and the telephone. St. Paul was not to be outdone in that respect, and the inhabitants accordingly represented their former post office when it came to their turn to have a procession. It was also put upon a wagon; it consisted of the old hat of the postman who was there forty years before. In the procession, not unfittingly, though it could not be regarded without a tinge of sadness, there were representatives of the Indian races, who so short a time ago had the whole land to themselves. They had similar receptions at a great many other places; at Bismarck, for example, where the foundation of a new State building was laid, and where they saw Sitting Bull, the old Indian chief who massacred the white people of that country a few years previously. They were presented at various places with a great display of the produce of the country, horticultural produce of all kinds. At Portland, near the Pacific coast, the population, about thirty thousand, were doing a very large trade. About 15,000,000 lbs. of salmon from the Columbia River had been put into tins and sent away in one season, a large portion being forwarded to England. From Portland they went to Vancouver's Island and Puget Sound, which was a beautiful sheet of water, with finely wooded banks. The people came with all sorts of banners, including the Union Jack and the flags of Germany and other countries. Many of the flags bore suitable mottoes for the instruction of the party, and one of them was "Modesty is a great virtue, but you get on better without it."

At one part of the line no timber was to be found, and it was a matter of great anxiety in making a railroad to find, that for 300 or 400 miles, no fuel was obtainable for the engines. Fortunately coal was discovered in the district, and at Billings and Bozeman, blocks of coal of a ton weight, had been brought from no great distance. The Westinghouse brake, almost universally used in America, was employed upon the trains by which the party travelled: and, on one or two occasions they had reason to be thankful that that brake was employed. The trains were very heavy, and the carriages, belonging to different railroad companies, did not always fit as regards the couplings. These accordingly had to be improvised, and once or twice it was a great comfort to the passengers to know that the Westinghouse brake was attached to the trains. One night the coupling of a carriage in which he was travelling with General Hutchinson broke, and their part of the train stopped. They were going up an incline, not a very steep one, and, but for the automatic brake, the carriages would certainly have run back, and there might have been a collision. General Hutchinson made an accurate note of the facts, which would no doubt be in future given as an illustration of the great importance of having automatic brakes on all English railways. A still more serious mishap arose from defective couplings. On going down an incline of 1 in 25, on the Rocky Mountains, a coupling broke. The front part of the train ran forward, and the engine-driver, discovering that he had lost part of his train, drew up, when the carriages behind ran into those in front, telescoping one of them to the extent of 4 or 5 feet. Fortunately no one was hurt, because those who were in the rear of the first section of the train, were at the front end of their carriage. This carriage contained the British Minister at Washington and his daughter, the German Ambassador and his wife, and one or two other persons of high official position. They were all very thankful to find that nothing more serious had happened. He mentioned the matter especially, because in America the Westinghouse brake, when used in descending an incline, was not worked automatically, but was controlled directly from the engine; so that, when an accident of that kind happened to the hinder part of the train, nothing could stop it, except in so far as hand-brakes might be applied at the moment. The accident would have been avoided had the brake been worked automatically.

He had previously mentioned, that at the Snake River, the trains were temporarily carried across on a ferry-boat. The boat was a comparatively small one. Two lines of railroad were laid upon it, and it would hold two large Pullman carriages at each side—four in all; or three carriages and a locomotive engine. The water was very low at the time. There was an incline of 1 in 15 leading from the railroad to the boat; and as the engine was descending with two carriages, one of the improvised couplings failed; the carriage ran down the incline on to the steamboat, and went against the chock at the other end of the boat; but fortunately no one was hurt, though some of the passengers were a little shaken. Two of her Majesty's judges, a member of the Privy Council, a member of the House of Lords, and her Majesty's Minister at Washington were occupants of the carriage at the time. The mishaps to which he had referred did not arise from any defect in the line, but simply from the improvised couplings.

The main ceremony for which the party had been asked to cross the Atlantic was the driving of the last spike of the railroad. It was called in the papers "the driving of the golden spike," but it was not of gold. The meeting was in the Rocky Mountains near a place called Garrison. It was not, as in England, to celebrate the opening of a railway, but to celebrate its completion. There was a length of ½ mile of the line unfinished; the sleepers were in their places, but the rails were not laid, and the Americans wanted to show the visitors how the work was effected. It was certainly done with marvellous quickness. A gang began at each end, and the ½ mile was laid in certainly not more than half an hour. The appliances were of a very ingenious nature; a wagon was drawn on carrying the rails; some men took these from the wagon and laid them in place, others followed and spiked them, and the two engines, one from the west, the other from the east, met on the last rail within half an hour. As he had said the spike was not a golden one; if it had been of course it would soon have been taken out; indeed, as it was, the last sleeper, spike and all, was pulled up within a very short time after it was laid, and he saw a bit of what professed to be the last sleeper of the Northern Pacific Railroad in a shop window in Portland, Oregon, about three days after the ceremony.

He had been much struck with the rapid growth of the cities along the route (every place was a city in America, however small). He had referred to St. Paul and other places forty years old; but other cities on the route with one thousand three hundred, one thousand five hundred, and two thousand inhabitants, were not more than two years or even fifteen months old. In the case of one town, named Billings, where there was a church, a schoolhouse, and a large variety of imposing buildings, he had the honour of being introduced on the platform to the first baby who had been born in the town, which was not more than one year old. Wherever the railway went population seemed to follow with the greatest rapidity. The houses were very good, generally of wood; and he was glad to say, as exhibiting a marked characteristic and element of strength in America, that generally the largest and most conspicuous building was the schoolhouse. Seattle was a young city on Puget Sound, and there he saw a very large school, and also a university.

He might be permitted to say one or two words with regard to what he had seen irrespective of the Northern Pacific Railroad. Much greater use was made of the electric light in America than in England. In some of the little outlying western cities a tall mast, with a couple of electric lights at the top, in the centre of the town, lighted the whole place. And not only in those western districts, where coal was perhaps difficult to get, but everywhere in America the electric light seemed to be much more used than in England. There were certainly some places where it might be adopted with advantage in England, and—he did not know whether it was heresy to say so—the meeting-room of the Institution was one of them. He greatly admired the steamers in America. He travelled in one of the most magnificent of them, the "Queen of the Pacific," from Tacoma to Vancouver's Island. It had a saloon about 30 feet high, and the fittings and arrangements were such as to put anything he had seen in this country in the shade. He thought there could not be a finer steamer than "The Pilgrim," of 3,500 tons, in which he had sailed from Fall River to New York. The electric light was used in that steamer, and also in the one in Puget Sound. He felt very small on arriving in the Mersey and landing from the Cunard steamer in the wretched tug-boats which brought the passengers to Liverpool, with not a dry seat to sit upon, and nothing to keep off the rain.

When at Chicago he went to see Pullman City, which was really the Pullman Works for the manufacture of railway carriages, a few miles out of Chicago. Three years ago the place was mere waste land, put to very little use. It was now a city of seven or eight thousand inhabitants. The works were fitted up in excellent style; but it was not the railway works themselves which chiefly interested him, for there were railway wagon works in England; it was the surrounding appliances. The Pullman Carriage Company had built houses for the workmen —not wretched-looking structures like colliers' cottages, but really good houses—in which the men lived at a much less rate than they would have to pay at Chicago or elsewhere. There was an arcade in which all the shops were beautifully laid out; and there was a subscription library to which any one could go by paying a small sum, and to which Mr. Pullman had given five thousand volumes. It was magnificently furnished, and he ventured to say that no nobleman's or gentleman's library in London was better arranged and fitted up than that built by the Company for their workmen. They had besides erected a theatre, which was attractively decorated. There was also a church, and two or three other large rooms for those who desired to attend places of worship, and a bank. Arrangements had been made by which the men could build houses for themselves on the unoccupied land. They could borrow money from the bank at reasonable interest, and, choosing their own spots, could build their own houses. Every thing was done in a way that he had not seen adopted anywhere else in order to lift the men above the mere work-a-day labour of their lives into something better. He was told that the work had succeeded, and was paying remarkably well.

In Chicago he saw street railroad cars drawn by wire ropes running underneath the surface of the street.[1] These were endless ropes, working as in a circle continuously, and the street cars were attached or released from the ropes by a catch or clip, which the driver of the car manipulated. The various lines were worked from one centre by a fixed engine. What the relative expense of this system was as compared with horses he did not know; but it was regarded as specially adapted for hilly roads. Those in Chicago, however, were flat. So far as he could judge it worked easily, though he was informed that a good many accidents had happened, and that people had been killed in the working of it.

In New York he was interested in observing the change which had been introduced since he was there twenty-four years ago. He referred particularly to the elevated overhead railroads.[2] These lines were carried upon iron columns and girders at a height of about 15 or 16 feet above the ordinary roadway between the rows of the houses on either side. This formed an extremely convenient and rapid means of communication, which, from the peculiar shape of New York, was of great value. But it would require the long-suffering American householder to put up with the disadvantages from which the residents in the adjoining houses suffered, in having to a large extent the light of their windows blocked out, and the privacy of their homes absolutely destroyed. There were positions in which this mode of construction would be of great value, where it could be used without injury to the quiet of residences which had been so much interfered with in New York. At the same time he was surprised to learn that the value of property in these streets had not only not deteriorated, but had rather increased.

The impression upon his mind throughout this trip had been one almost of envy towards the engineers of America for having a land so big to deal with in the practice of their profession, and at the same time he felt continually disposed to congratulate them upon the spirited way in which they grappled with difficulties, and the successful way in which they had overcome them. There was certainly no jealousy between the engineers of America and England. Englishmen felt that they had some right to share in the satisfaction with which they looked round upon their country and saw what they had done for it; for was not America the evolution of England? And they were thus entitled to be sharers in each other's triumphs.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 210.

[2] *Ibid.*, vol. lxviii., p. 229.

During the trip they received the greatest attention and courtesy from Mr. Villard, the President of the Northern Pacific Railroad, and from the other Directors and Agents connected with it, and from General Anderson, the Chief Engineer of the road, whom he heartily congratulated upon the near completion of this enterprise. And as the difficulties which had been encountered by the Company, financial and otherwise, had been nobly overcome, so he hoped that, in the very near future, all interested in it might receive the due reward of their labours.

It was impossible not to be impressed with the extraordinary hospitality of the American people. In Portland, Oregon, for instance, where there were few hotels, the party were received into the private houses of the citizens of the place, and right hospitably entertained, and everywhere they were, as opportunity offered, received in the same way. America was a great and magnificent country; great and magnificent in the extent of its territory; great and magnificent in what it had achieved in the past in turning the wilderness into a fruitful garden; great and magnificent in the future which lay before it. The representatives knew all this upon ample testimony, because they had been told it by others and had read of it in books for themselves. But it required a trip across the Atlantic, to brave all its storms and to visit America as the guests of Mr. Villard and the Northern Pacific Railroad Company, and to be the guests of the towns and cities along its route, in order to know, as they now most certainly did, that America was great and magnificent even in its hospitality.

Discussion.

Sir James Hannen.

The Rt. Hon. Sir JAMES HANNEN said the only point on which he dissented from the observations of Mr. Bruce was, that he sincerely wished elevated railroads might be introduced into London. It had been admitted that they were most convenient for the passengers, and he had himself been assured, by those who had a good opportunity of knowing what the facts were as to the effect upon the houses, that the householders had not been able to recover any compensation, so little did the rest of the population consider that the houses had been damaged. They were certainly a most convenient mode of getting from one part of a large city to another. The party had had the opportunity of enjoying a most delightful trip. It was a sad thing to reflect that one of the greatest sources of wealth to which the Northern Pacific Railroad Company must look in the future, their timber, or lumber, as they called it, was being wasted by the fires that were constantly taking place. If a man wanted to boil his kettle he was perfectly regardless whether or not he burned down a mountain side of timber. The remarkable bridges which had been described were in the midst of forest fires that might seize them at any time. It was true that the precaution had been taken of placing at intervals, he did not know of how many yards, some tubs of water, to be used in case the bridges should take fire; and when one of the four trains which conveyed the party was passing over one of the bridges, it was actually on fire, and the passengers had to get down and ladle the water out of the buckets. That was certainly a subject of considerable anxiety to some of them. They were informed that there were four men whose duty it was to watch the bridge to see that it did not catch fire, but where those four men were at the time he did not know. Another disadvantage of that reckless mode of dealing with timber was, that they had not the opportunity of seeing the scenery of the country. Nothing could exceed the beauties of the Columbia River. For this was worth making a journey to America; but it was only, as it were, by the accident that a little rain had fallen, they were able to see it at all, for the country for a thousand miles was darkened by the forest fires. Mount Hood, a magnificent mountain, clothed with snow, had not been visible for three months for the smoke. He might ramble on, for the experiences of the journey had been of a most interesting kind, but he would only say, in conclusion, that he not only thought that engineers would be interested in seeing the great work which had been described, but (and he said it most emphatically) that every Englishman who had the opportunity ought to go to the United States. He did not understand his own country and his own countrymen until he saw what men of the English stock might become by being transplanted to the United States. Sir James Hannen.

Mr. JOHN HOLMS, M.P., had been greatly delighted in listening to Mr. Bruce's address. He had heard with pleasure the speech which Mr. Bruce had delivered at Walla Walla, to which he had referred, and in which he had maintained the position of engineers in a very modest and admirable manner. He quite agreed with Mr. Bruce in what he had said as to the hospitality shown to them throughout their whole stay in America. Everything had been done that was possible to make the trip not only agreeable but instructive. He was inclined to dissent from Sir James Hannen in regard to the desirability of having elevated railroads in London. He should be exceedingly sorry to see them introduced, unless it was done in the ordinary way in which things were carried out in this country, by asking the sanction of the people before their houses were affected. In America such matters were dealt with very freely and easily. The railroad was first made, and people travelled by it, and then the houseowners were left to get compensation for the damage to their property. He should certainly regret to see a railroad of that kind in the Strand or Cheapside. It might possibly be introduced in Hammersmith or other out-of-the-way places, but he should be sorry if such a railroad were introduced in a central part, as had been done in New York. He thought that no one who wished to understand his own country or Europe could do better than to visit the United States of America. He travelled in America in 1854, when the West was a mystery, and was always spoken of as the "Far West." None of the four railroads, the Southern Pacific, the Central Pacific, the Northern Pacific, and the Canadian Pacific (soon to be completed) had been touched, and even Chicago was a small village. He had told the American people, and he repeated the observation, that their country looked smaller now, when it was possible to go by railway from one side of it to the other, than it did in the mysterious days to which he had referred. Mr. Bruce had given an excellent picture of their journey, and of everything they had seen and learned. He had been more especially struck, like Mr. Mr. Holms.

Mr. Holms. Bruce, with the fact that wherever they went the schoolhouse was a prominent building. In the small city of Bozeman, for instance, the two most prominent buildings were the two great schools. It was an admirable lesson to help forward education as much as possible.

General Hutchinson. General HUTCHINSON observed that Mr. Bruce had given a graphic and able description of the expedition, to which very little could be added. With regard to the general mode of working the single lines in America, he might say that they were entirely worked by telegraph. He had talked with many of the managers and superintendents on the subject, who had told him that they had not the least difficulty, and that they never had any accidents. In his last conversation on the subject he had said that that was not the experience in England; that the telegraph had not been found to be thoroughly reliable, and that the train-staff system had to be employed. On the following morning he had read in the papers an account of a bad accident on a single line close to New York, in which several lives had been lost owing to some mistake in the mode of conducting the traffic by telegraph. Of course that did not disabuse him of the idea that it was wise to use some precaution beyond the telegraph in working single lines. In regard to the facilities for constructing railways alluded to by Mr. Bruce, there was one point that he had not actually seen but had heard of, which had greatly struck him, namely, the mode by which the lines were ballasted. A number of trucks loaded with ballast, but nothing like the number of men employed in England, were taken to the part of the line where the ballast was to be deposited. On the last truck there was a plough, attached to which was a rope passing over all the trucks, and fastened to the engine in front. The side- and tail-boards having been let down, the engine went on, and the plough ran through the trucks turning the ballast off as it went along. The operation required very few men, and the work was speedily done. The method might perhaps be adopted in certain cases in England. Through the kindness of its President, he had had the opportunity of going over the New York, West Shore, and Buffalo Railway, one of the new lines just constructed in America. The principal feature of it was the wide central space between the lines of rails, no less than 10 instead of 6 feet as in England, or 15 feet from centre to centre of the roadways. The President told him that, as far as his experience went, he believed that would be the mode adopted in America in future, where sufficient land could be obtained, the object being to reduce the danger arising from an accident on one line

General Hutchinson.

fouling the other. The line was about 400 miles in length, extending from New York northward to Albany, and beyond. Another feature they had introduced was a pneumatic system of signalling. In dangerous parts of the line they thus worked signals from a point perhaps 800 yards distant, by simply touching a small key, which acted on the air in a pipe and set the signal to "Danger." They had also some novel electrical arrangements connected with their method of signalling, which were very interesting but rather too complicated to explain on the present occasion. With reference to the trestle bridge nearly being burnt, he had heard a description of it from the man who put the fire out, and perhaps it might interest the members to hear it. The last of the four trains was stopped upon the viaduct owing to some failure in the engine, and the last carriage of the train stopped about the centre of the viaduct. The gentleman who gave him the description was the Assistant General Manager of one of the St. Paul's railroads, a very energetic man, who had nailed the first and last spikes of the Northern Pacific line. When the train stopped he went out on the gangway of the car, and looking down, saw a piece of live coal or cinder resting where two timbers met in a trestle, about 20 feet below. He sent for a bucket, filled it with water from one of the casks alluded to by Sir James Hannen, and, having got down as far as he could, sluiced the water over the piece of coal just as it was bursting into flames. The fire had not proceeded quite so far as some persons had thought, but of course if it had not been seen it would have been a very serious matter. Mr. Bruce had alluded to the value of the automatic brake in one case, and to the want of it in another. Those were certainly points to be borne in mind in regard to the use of brakes. As to the non-use of the automatic brake in descending gradients, he was sorry to say he had not yet been able to ascertain the exact reason. The custom prevailed, he believed, only upon very steep gradients. Mr. Bruce and he were together at the top of one of the passes when the following conversation took place with a driver. They were debating whether they should walk down or wait for the train to overtake them, and he said to the driver at the summit, "Do you think the train is sure to stop here and pick us up?" The man replied, "It is bound to stop, because the driver has got to change his air." On being asked the meaning of what he had said, he replied, "Well, we come up the hill automatic, but we go down straight." That was still somewhat enigmatical, because he did not know what was meant by "going down straight." On

General Hutchinson. being further questioned, it appeared that the man had to change the automatic character of the brake, and make it directly applicable from the engine. "Surely," General Hutchinson said, "there is a risk of accident if a coupling breaks when the train is going down." "Well," said the man, "there is very little chance of that: the fact is we cannot work down these steep gradients automatic; we must do it straight." On getting to the bottom they found what Mr. Bruce had described—that there had been a telescoping of the car in which the British Ambassador and others had been travelling, from the fact that the train had broken in two, and that from the want of automaticity in the brakes the rear portion had run into the front. If the train had been fitted with automatic brakes, no such accident would have occurred. One thing that had struck him in the United States was the absence of any roof-loading on the cars and omnibuses. He mentioned the subject because, in the extended use of steam-traction on tramways, roof-loading was no doubt a dangerous feature. The fatal accidents that had occurred in this country had almost entirely happened to passengers who had been carried on the roofs of the vehicles. He did not see why the custom of the United States, of having the cars and omnibuses loaded inside only should not by degrees be adopted in England. He could quite endorse Mr. Bruce's remarks with regard to the overhead railroads, and, like Mr. Holmes, he should be sorry to see them introduced into the streets of London, or of any large towns, where they would be, in his opinion, an intolerable nuisance. Happily, in this country, the consent of the frontagers had to be obtained before such things could be done. In America the work was done first, and the frontagers had to get their remedy afterwards. He believed that the question of compensation to frontagers was still before the United States Courts, and was not likely to be settled for some time. He desired to express his own sense of the great and magnifient hospitality with which the party, of which he was fortunate enough to be one, had been treated by the Northern Pacific Railroad Company, and by many of the towns where the expedition had halted.

Mr. Brunlees. Mr. Brunlees, President, moved a vote of thanks to Mr. Bruce, which was passed by acclamation, alike for the narrative he had given, and for devoting so much of his time, and undertaking so long a journey, on behalf of the Institution.

20 November, 1883.

JAMES BRUNLEES, F.R.S.E., President,
in the Chair.

After taking the Chair, the President rose and said: It is with the deepest sorrow that I have to inform you of the death of our highly-valued and esteemed Member of Council, Sir William Siemens, which took place last night after a short illness, believed to have been the result of a fall two weeks ago. Sir William was a man whose power of intellect, and whose services in the application of practical science to almost every branch within the range of the profession of the civil engineer, were universally appreciated. His fame was world-wide, as it deserved to be; and those who knew Sir William Siemens best will be the most ready to acknowledge that the qualities of his heart were no less conspicuous than those of his intellect. The Council are sure that they will best consult the feelings of all present by proposing to adjourn this Meeting, as a mark of respect to the memory of one who was so greatly honoured and beloved.

On the motion of Sir James Ramsden, seconded by Mr. Shelford, it was resolved, "That this Meeting desires to record the deep sense of the loss the Institution has sustained by the death of their eminent and highly-esteemed colleague, Sir William Siemens, and its sincere sympathy with Lady Siemens in her irreparable bereavement."

The Meeting was thereupon adjourned to the 27th of November.

27 November, 1883.

JAMES BRUNLEES, F.R.S.E., President,
in the Chair.

(*Paper No. 1960.*)

"The New Eddystone Lighthouse."

By William Tregarthen Douglass, Assoc. M. Inst. C.E.

In a note submitted to the Institution by Sir James Douglass, M. Inst. C.E., during the session of 1877-78, the necessity was explained for the substitution of a new lighthouse for Smeaton's famous structure, which, having withstood the storms of more than a century with incalculable advantage to mankind, was stated to be "in a fair state of efficiency; but, unfortunately, the portion of the gneiss rock on which it is founded has been seriously shaken by the incessant heavy sea-strokes on the tower, and the rock is considerably undermined at its base. . . Unfortunately, the waves rise, during stormy weather, considerably above the summit of the lantern, thus frequently eclipsing the light, and altering its distinctive character."[1] The latter defect was of little importance for many years after the erection of Smeaton's lighthouse, when individuality had not been given to coast-lights, and no signal-lights were carried by shipping; but with the numerous coast- and ship-lights now visible every night on the seas surrounding this country, a reliable distinctive character for every coast-light has become a matter of absolute necessity.

The Trinity House having in 1877 determined on the erection of a new lighthouse, their Engineer-in-Chief was instructed to survey the site and submit a design for the proposed structure (Plate 2), together with an estimate of the cost, including the removal of the upper portion of Smeaton's lighthouse, namely, that above the level of the top of the solid work, such removal being necessary for the security of the lower portion.

The site selected for the new tower is 120 feet south-south-

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[1] Minutes of Proceedings Inst. C.E., vol. liii., p. 247.

east from Smeaton's lighthouse, from centre to centre. It will be observed from the section (Plate 1), that there is no probability of the rock at this point becoming undermined, the tower being founded in the actual body of the reef, with no surrounding point of attack at a lower level. The only drawback to the site was that a large portion of the foundation had to be laid below the level of low-water spring-tides.

The estimate submitted for the work was £78,000. The design and estimate having been approved by the Trinity House, and the necessary statutory sanction procured for the outlay, tenders for executing the work were obtained from six contracting firms experienced in sea-works; but as the lowest tender was considerably in excess of the estimate of the Engineer-in-Chief, it was determined that the work should be executed by him without a contractor.

Mr. Thomas Edmond, who had been engaged for several years in the service of the Trinity House in the erection of lighthouses, was selected for the superintendence of the work, and the Author was appointed the Assistant Engineer. The whole work of fitting up the internal arrangements, together with the taking down and removal of Smeaton's lighthouse, was afterwards entrusted to the Author, the services of Mr. Edmond being required at another important work.

A suitable site for the workyard on shore was obtained at Oreston, on the River Laira, Plymouth. The site, which is a portion of the premises formerly appropriated for the construction of the Plymouth breakwater, and is now partially used for its maintenance, was kindly placed at the disposal of the Trinity House by the Lords of the Admiralty. Here a temporary timber jetty, workshops, stores, offices, &c., were erected.

The twin screw-tender "Hercules," one of the two steam vessels employed in the construction of the Great and Little Basses Rock Lighthouses, Ceylon, having returned to this country on their completion, was transferred to the station at the Eddystone as the working tender. This vessel (Plate 1), with her special adaptability for lighthouse-building, has been described by Mr. William Douglass, M. Inst. C.E., in a Paper on the Great Basses Lighthouse.[1]

The structures of Winstanley, Rudyerd, and Smeaton having been so fully alluded to by Smeaton in his "Narrative of the

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[1] Minutes of Proceedings Inst. C.E., vol. xxxviii., p. 50.

building and a description of the construction of the Edystone Lighthouse," need no further reference.

The tendency of the curvilinear outline of Smeaton's and of other similar sea-towers that have succeeded it, to elevate the centre of force of each wave-stroke on the structure, induced Sir James Douglass to adopt a cylindrical base for the new lighthouse, from which base, at a level of 2½ feet above high-water spring-tides, the curved shaft of the tower commences. The difference in the rise of heavy seas on the two structures during stormy weather is remarkable. The cylindrical base has the further advantage of affording a convenient landing platform, thus adding considerably to the opportunities of relieving the lighthouse.

The base is 44 feet in diameter by 22 feet in height. The tower is a concave elliptic frustum, the generating curve having a semi-transverse axis of 173 feet, and a semi-conjugate axis of 37 feet. With the exception of the space occupied by the fresh-water tanks, the tower is solid for 25 feet 6 inches above high-water spring-tide level. At the top of the solid portion the wall is 8 feet 6 inches in thickness, diminishing to 2 feet 3 inches in the thinnest part of the service-room. All the stones are dovetailed both horizontally and vertically, on the system described by Sir James Douglass in his Paper on the Wolf Rock Lighthouse.[1] Each stone of the foundation-courses is sunk to a depth of not less, at any part, than 1 foot below the surface of the surrounding rock, and is further secured by two Muntz metal bolts, 1½ inch in diameter, passing through the stone, and 9 inches into the rock below, the top and bottom of each bolt being fox-wedged.

The tower is approached for landing on two sides, the north-east and the south-west. At each of these points, in a recess made in the face of the cylindrical base, are fixed gun-metal cleats affording access for ascending to the landing platform. From this point the entrance is reached by another ladder formed of twenty-five similar cleats. In the fourth, or store and coal-room, are two doors, one directly over each landing place, for receiving the stores, which are hoisted direct from the boat by a sliding crane, working through a port in the tower over each door, and arranged to house within the tower during stormy weather. This crane is also used for landing and embarking the lightkeepers and others, when the sea will only admit of a boat approaching with safety within from 20 to 40 feet of the tower.

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[1] Minutes of Proceedings Inst. C.E., vol. xxx., p. 1.

The tower contains nine rooms, the seven uppermost having a diameter of 14 feet and a height of 10 feet. These rooms are fitted up with every consideration for the accommodation of the light-keepers, and the stores necessary for the efficient maintenance of the lights; they are rendered as far as possible fireproof, the floors being of granite covered with slate, the stairs and partitions of iron, and the windows and shutters of gun metal. The two oil-rooms contain eighteen wrought-iron cisterns capable of storing 4,300 gallons of oil, and the water tanks contain, when full, about 4,700 gallons. The section and general arrangement of the lightning conductor are as originally recommended by Faraday. The section is 1½ inch by ⅜ inch half-round copper; the rod is carried down inside the tower from the lantern pedestal to the entrance door, and is let in flush with the surface of the walls, to which it is secured at every 3 feet by lead plugs and copper screws, the several lengths being lapped and screwed together at the junctions. The gallery railing, metal floor of the lantern, windows, window-shutters, external doors, iron partitions, tanks, ladders, lead pipes, crane, stoves, &c., are all properly connected with the conductor, by copper of the same section. From the entrance door the conductor is continued down the face of the tower to a depth of 2 feet below low-water spring-tides.

The masonry consists of two thousand one hundred and seventy-one stones, containing 62,133 cubic feet of granite, or 4,668 tons. Around the wall of the service-room is neatly sunk, in the course under the ceiling, the verse of Psalm cxxvii., as adopted by Smeaton on the wall of the oil-room of his lighthouse, "Except the Lord build the house they labour in vain that build it."

The lantern (Plate 4) is the cylindrical helically-framed type adopted by the Trinity House, a description of which has already been submitted to the Institution.[1] The glazing is 2 feet 6 inches higher than usual for first-order lights, this additional height being necessary to meet the requirements of the special dioptric apparatus. The flag-staff (Plate 2) is fixed in a hole cut through the lantern-gallery, and in a gun-metal guide at the surface of the tower below. At night the flag-staff is lowered by a winch, with which it is provided, so that its truck is below the level of the beams of light issuing from the lantern. For the white fixed light exhibited from the three lighthouses of Winstanley, Rudyerd, and Smeaton at the Eddystone, the Trinity House determined on substituting as a distinction for this important

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[1] Minutes of Proceedings Inst. C.E., vol. xxviii., p. 11.

station, a white double-flashing light at half-minute periods, showing two successive flashes, each of about three and a half seconds' duration, divided by an eclipse of about three seconds; the second flash being followed by an eclipse of about twenty seconds. It was also determined to show from a window in the tower, 40 feet below the flashing light, a sector of white fixed light, covering a dangerous shoal called the Hand Deeps, which bears north-west from the lighthouse at a distance of 3½ miles (Plate 1). It was further determined that a large bell should be sounded during foggy weather, twice in quick succession every half minute; thus assimilating the character of the sound-signal to that of the light. Two bells of 40 cwt. each are mounted at opposite sides of the cornice, in order that a windward bell may be sounded during fog.

The optical apparatus of the main light (Plate 4), consists of two superposed tiers of lenticular panels, twelve in each tier. The section of these lenses was designed by Dr. John Hopkinson, M. Inst. C.E., in 1880, for the Anvil Point lighthouse on the coast of Dorsetshire. Each lens-panel subtends a horizontal angle at its foci of 30°, and a vertical angle of 92°, being 47½° above the central plane of the lens, and 44½° below it. Each lens-panel is composed of a central lens and thirty-nine annular rings or segments, there being twenty-one above and eighteen below the central lens. The twelve panels in each tier are fitted together so as to form a twelve-sided drum, each lens having its focus in a common centre at a distance of 920 millimetres. These lenses subtend the largest vertical angle of any yet constructed for coast-illumination, the increased angle and consequent additional power being obtained by the adoption of heavy flint glass for the six highest and for the three lowest rings of each panel. The relative efficiency of this section of lens and that of the old section is 88 to 70 nearly, and its effect is only about 12 per cent. less than that of the old apparatus composed of lenses with totally-reflecting prisms above and below it. Various combinations of superposed optical apparatus have been employed in the lighthouses of this country since the application by Faraday in 1843[1] of ventilating tubes to each lamp, for conveying to the cowl of the lantern the products of their combustion. In 1859 Mr. J. W. D. Brown, of Lewisham, proposed superposed lenses for signal and lighthouse-lanterns, with a separate light for each tier of lenses. In 1872, Mr. John Wigham, of Dublin, proposed superposed lenses for lighthouses, and the first application of these, in conjunction

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[1] Minutes of Proceedings Inst. C.E., vol. xi., p. 188.

with gas-flames, was made by him in 1877, at the Galley Head Lighthouse, on the coast of County Cork. In 1876 Messrs. Lepaute and Sons, of Paris, appear to have made successful experiments with superposed lenses, and the mineral oil flames of one to five-wick lamps, the results of which were given by Mr. Henry Lepaute, Jun., in a paper contributed to the Congress at Havre in 1877, of the French Association for the Advancement of Science.[1] Messrs. Lepaute and Sons also exhibited an apparatus of this kind at the Paris International Exhibition of 1878. The Eddystone represents, however, the first practical application of superposed lenses of the first order with oil as the illuminating material. Access to the burner is obtained, as in all recent first-order lights of the Trinity House, by a door in the large circular pedestal, and a man-hole in the lamp stage, so that entire control of the manipulation of the lamp or lamps is exercised by the lightkeeper without the usual stoppage of the rotation of the apparatus, and consequent interference with the distinctive character of the light. The lantern and optical apparatus were constructed by Messrs. Chance Bros. and Co., of Birmingham.

The flame of a six-wick "Douglass" burner, with an intensity of 720 candles, is placed at the common foci of each tier of lenses. For these burners others of seven wicks will shortly be substituted, having an intensity of 950 candles. The ventilation of the upper burner is provided in the usual manner, by an iron funnel carried up to the ventilating shaft of the lantern, with a regulating damper. For the ventilation of the lower burner, the funnel is divided into three branches, and these are carried up inside the upper lenses, to the same level as the funnel of the upper burner. Each branch is flattened where it passes the upper lenses, thus reducing to a minimum the obstruction of the light in its passage from the burner to the lenses. It will be observed that the small obstruction of light thus incurred might be avoided by carrying the flues from the lower burner upwards on the outside of the upper tier of lenses, and in the dark spaces between the beams sent from the lenses. This arrangement would probably be necessary with an apparatus composed of three tiers of lenses, to avoid the high temperature created inside them. It was, however, considered preferable in this instance to obviate the further complication of the apparatus that would have been incurred.

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[1] Compte rendu de l'Association française pour l'avancement des sciences 6ᵉ Session, p. 223.

As the first application of the improved burner of Sir James Douglass to a coast lighthouse of the first order was effected at the Eddystone, a description of this burner, which is shown in Plate 5, is desirable. The invention consists in surrounding an ordinary deep-chambered Argand, or a concentric-stepped Argand-burner for oil or gas, with two or more concentric deflectors, these deflectors being so arranged, in conjunction with a deflecting glass chimney, as to force, in successive stages, the outer flame or flames on to the inner flame or flames, thus condensing them to the utmost extent, and also deflecting on to the external and internal surfaces of each ring of flame, the whole of the ascending currents of air. The initial temperature of the flames is thus considerably increased by the condensation, and the temperature of the ascending currents of air is raised in their passage through the burner to the flames; perfect combustion being consequently produced with a maximum intensity of the light, and a minimum consumption of the illuminating material. With this burner no adjustment of the shoulder of the glass chimney is required, as usual with concentric Argand lighthouse-burners; consequently no alteration is made in the position of the zone of light of maximum intensity, which is generally adjusted to the optical apparatus for direction to the sea-horizon. By the arrangement of the currents of air through the deflectors, the internal surface of the glass chimney is maintained in a clean and efficient state, and the temperature of the glass chimney is considerably lower than ordinarily with Argand burners; thus flames of much greater intensity than hitherto produced can be employed without risk of breakage of the glass chimney. An intensity of nearly 1,500 candles has been obtained with these burners, without damage to the glass chimney, and the intensity per square inch of the sectional area of the flames in the vertical plane is believed to be the highest yet obtained with any burner for oil or gas. The simplicity of construction of the burner, the high intensity and focal compactness of its flame, together with the economy of fuel, combine to render it, in the Author's opinion, the most efficient burner yet produced for any illuminating oil or gas.

The placing of the lamp in the pedestal of the illuminating apparatus affords more room for the lightkeeper in the manipulation of the burner than when set on the lamp-stage in the usual way; moreover it is a much safer arrangement as regards fire where mineral oil is consumed.

The improved lamp-reservoirs and pumps for the supply of oil to the burners (Plate 5), two of which are provided, were designed by Sir James Douglass for the Anvil Point lighthouse in 1880.

The improvements in these lamps consist in the introduction of a hollow weighted plunger for driving the oil to the level required for each burner; also the application of a double-acting pump for raising the plunger, in lieu of a rack-and-pinion, or a pitch-chain with weights as hitherto. The apparatus is less costly and less liable to accident than the different lighthouse lamps now in use. The only parts subject to wear are the pump leathers, and new ones are substituted by the light-keepers whenever required. Two reservoirs and plungers are ordinarily in use, but the light can be maintained by one, so that in case of accident to either, the disabled lamp can be disconnected and sent ashore for repairs.

The driving-machine is arranged for striking the fog-bells, in addition to the rotation of the optical apparatus. The machine is driven by an endless balanced pitch-chain with arrangement for maintaining the power during the process of winding. The driving weights are placed in an iron trunk in the lower rooms of the tower, and are connected with the pulleys and pitch-chain by a ¾-inch chain, the latter passing through an iron tube at the centre of the tower. A small "Buckett" caloric engine, of ½ effective HP. (Plates 2 and 3), is intended to be fixed in the service-room, for relieving the lightkeepers of the excessive strain of driving the machine when both illuminating apparatus and fog-bell are in use. The engine is now under practical trial at the workshops of the Trinity House, preparatory to its being fixed at the lighthouse. The speed of the machine is regulated by a "Slight" centrifugal governor, and is provided with an indicator dial; also gear for rotating by hand in case of accident to the machine. With a clear atmosphere, and the light of the Plymouth Breakwater lighthouse 10 miles distant distinctly visible, the lower burner is worked at its minimum intensity of 450 candles, giving an intensity of the flashes of the optical apparatus of 37,800 candles nearly; but whenever the atmosphere is so thick as to impair the visibility of the Breakwater-light, the full power of the two burners is immediately put in action with the aggregate intensity of 1,900 candles for the lamps, and an intensity of the optical apparatus of 159,600 candles nearly. This intensity is about 23·3 times that of the fixed light latterly exhibited from Smeaton's tower, and about 2,382 times that of the light first exhibited in the tower from tallow candles. The intensity of the light is the highest that has yet been produced from oil for coast illumination.

The optical apparatus for the lower fixed light consists of two

21-inch paraboloidal reflectors, each fitted with a two-wick "Douglass" lamp. The intensity of this light is nearly 12,000 candles.

The focal plane of the upper light is 133 feet above high water. Its nautical range is 17½ miles, and during clear weather it overlaps the electric lights at the Lizard Point.

The Eddystone furnishes good evidence of the recent progress in lighthouse illumination, and of the enormous value of perfect optical apparatus for the utilization of the illuminant, both with regard to economy, and its efficient service for the guidance of the mariner.

The original chandelier-light in Smeaton's lighthouse was unaided by optical apparatus; it consisted of twenty-four tallow candles, weighing ⅜ lb. each. The intensity of the light of each candle has been found from experiments made by Sir James Douglass to have been about 2·8 standard sperm candles, thus the aggregate illuminating power radiating from the twenty-four candles was about 67·2 candle units. The consumption of the candles was about 3·4 lbs. per hour and the cost of the light per hour, at the current price of tallow candles, would be about 1*s.* 6¾*d.*

At the shore lighthouses of the Trinity House, where oil is employed as the illuminant, mineral oil is adopted as being the cheapest, while in point of efficiency it is equal to the best of the vegetable or animal illuminating oils. At the Eddystone, as at other rock lighthouses, as well as on board light-vessels, colza-oil is employed on account of its greater safety in use and storage. For the whole year during which the lamps of the main light at the Eddystone are burning between sunset and sunrise—four thousand four hundred and twelve hours—being about two thousand nine hundred and forty-one hours clear weather, and one thousand four hundred and seventy-one hours thick weather, the cost of the illuminating oil per hour, inclusive of wicks, and glass chimneys, is 1*s.* 7¼*d.* nearly, being only ½*d.* more than the present cost per hour would be of the original candle-light at this station of only $\frac{1}{2382}$ part of the intensity of the present light.

The first visit of the Engineer-in-Chief and working party was made in the "Hercules" on the 17th of July, 1878. The weather being very favourable, with full spring tides, a large portion of the area was uncovered at low water, and a commencement was made with the work. The site was examined with the view of avoiding any unnecessary removal of sound rock, and the exact positions of the various benchings of the foundation courses were carefully traced out, and permanently pegged for the guidance of the workmen. At the centre of the site a commencement was made in the levelling in benches, of an area having a radius of 10 feet 8 inches, and building in Portland cement, and protected with fresh burnt Roman cement, with small rough granite ashlar, of 1 to 1½ cwt. per stone (a convenient size for landing from the boats), a central platform and future core for the work. At the centre of this platform a 2-foot well-hole was formed for the central crane, and in this the men worked in sinking the required hole in the rock for supporting the crane.

The platform, raised 10 feet above low-water spring tides, considerably facilitated the earlier stages of the work, as the workmen could land with their tools and materials, in readiness for proceeding with the work to the foundations, immediately the tide had sufficiently ebbed; and, with the flood tide also, they were thus able to continue at work until the last possible moment. Around the foundation, and at a distance of 6 inches from the face of the masonry of the cylindrical tower, a strong cofferdam of hard well-burnt bricks and fresh burnt Roman cement was built. Every available opportunity by night or day was seized for getting in this dam. Before laying the bricks, the surface of the rock was well cleaned from sea-weed and rough picked, the cleaning being effected, where the rock was exposed, by strong sulphuric acid. The cofferdam was 7 feet in thickness at its base, with a maximum height of 7 feet. Three radiating walls were formed in the dam as shown in Plate 1, these being required: (1) For strengthening the dam; (2) For reducing to a minimum the quantity of water to be ejected at each tide before commencing work; (3) For affording, as they frequently did, a lee dam for carrying on the work, when otherwise it would have been impossible to keep the whole area free from water. For protecting the work whilst the portions of the dam on the south and west sides, at about 2 feet below low-water spring-tides, were being built, heavy bags of concrete were at first deposited along the outside radius of the dam. Occasionally a few courses of brickwork were found to have been washed away on the return of the party to the rock; but fortunately no great damage ever occurred to the cofferdam. Sharp grit-sand of excellent quality, composed chiefly of hard quartz, was obtained from the bed of the River Plym at Plympton for the cement of the cofferdam and tower.

For removing the water from the dams at each tide, the "Hercules" was moored at about 30 fathoms from the rock as hereafter described. From the steamer to the rock were passed two 3-inch india-rubber canvas-covered hose, internally wired. These were connected to the double-acting pumps of the fore-and-aft steam-winches. The water was thus removed from one section of the dam by steam-power, assisted by the workmen with buckets on the rock, in about fifteen minutes in favourable weather; the full complement of men then started work whilst the other dams were being emptied by the hose. As no blasting was allowed in removing the superfluous rock, for fear of shaking the foundation, the whole work had to be executed by drills, jumpers, cleaving-gear, and picks, and, as each face-stone is sunk to a depth of not less than 1 foot below the surrounding rock, a considerable amount of labour of this description had to be performed. This portion of the work was considerably facilitated by the use of two of the "Eclipse" rock-drills of Messrs. Hathorn and Co., which were very efficient, and needed little repair. These drills were driven by compressed air, at a pressure of 80 lbs. per square inch, supplied through a flexible hose from a pair of compressors on board the "Hercules."

For landing stone the "Hercules" was moored at about 30 fathoms from the rock, as shown in Plate 1, ahead by 10-inch coir hawsers to three iron spherical buoys, attached with 1½-inch open-link chain to 40-cwt. cast-iron sinkers, and astern to iron posts on the surrounding rocks. The end of each hawser was provided with a chain for fastening to the ring of the buoy, and to this was attached a tripping-line, for use in case of rough weather coming on suddenly, when the whole of the hawsers could be let go from the vessel without any aid from a boat.

A hollow wrought-iron mast, 25 feet in length and 16 inches in diameter, was firmly wedged in a hole at the centre of the tower, sunk 5 feet into the solid rock, and stayed by ¾-inch guy-chains. Two jibs were attached to the mast, one of wood for landing the stones, and one of iron capable of travelling around the mast for setting. The wooden jib at the early part of the operations was lowered and taken off at the end of each tide's work, to avoid its being damaged by the sea; but the iron jib was lowered and securely lashed to eyebolts on the structure, and its winch stowed in the central hole, or removed on board the "Hercules" to avoid all risk of its being broken or lost. As the work progressed, the iron mast was lifted by hydraulic jacks and secured to the structure by timbering and chain back-guys. A hollow wrought-iron topmast, 19 feet in length, was fixed to the mast, after the second season, to obviate the frequency of lifting.

The "Hercules" being safely moored in her berth at the rock, the stones were lifted from the hold by the forward steam-winch and deposited upon a truck, which ran on metals to the stern of the vessel, where a strong timber gantry was erected; and wooden rollers were fitted on the deck at the stern gangway for carrying the stones clear of the stern of the vessel without damage. The stone standing on the truck under the gantry at the stern, was landed by the after double-barrel winch in the following manner. A $\frac{9}{16}$-inch chain-fall was passed from the starboard winch end, through a leading block at the side of the gantry, and thence successively to a leading block at the heel of the landing mast, next to a block attached to the head of the landing jib, then to a single block shackled to the lewis of the stone, and finally to the head of the landing jib, where it was made fast. A second chain, $\frac{5}{8}$ inch, was passed from the port barrel of the winch over a strong sheave fixed on the top of the gantry, and shackled to the lewis of the stone. On the starboard barrel of the winch being put in motion, and the chain-fall fairly tightened, the stone was lifted clear of the truck by the port barrel, and then eased away by a break as the stone was hauled on shore. For landing the stone on the tower, a strong luff-tackle was attached at one end to the mast of the crane, at about 11 feet above the level of the top of the masonry. Immediately the stone was hoisted well above the top of the work, the hoisting winch was stopped, and the luff-tackle was promptly hooked to the sling of the stone, and the end of the tackle-fall was made fast. The signal to lower was then given, when the stone was immediately landed on a strong coir mat placed to receive it. The stones, weighing from $2\frac{1}{2}$ to $3\frac{1}{4}$ tons, were transported between the stern of the vessel and the tower in two-and-a-half to three minutes. On being landed, they were removed by the traversing-jib to their several positions, and set by hand. Three of the positions of the crane, which worked successfully throughout, are shown in Plate 1. Thus every stone in the building, together with the required cement, sand, water, &c., was landed and hoisted on to the work at one lift from the "Hercules." This is probably the first application of floating steam machinery to the actual erection of a structure at sea.

By June, 1879, the work was sufficiently advanced for the stones to be laid in the foundation-courses, and everything was arranged for H.R.H. the Duke of Edinburgh, Master, who was to be accompanied by H.R.H. the Prince of Wales, Elder Brother, of the Trinity House, Hon. MM. Inst. C.E., to lay the foundation-stone on the 12th of the month. The weather had been rough for many days previous to the one set apart for the ceremony, but hopes were entertained of its clearing up. When, however, the morning broke, the wind was blowing a gale from the south-west, and a landing at the Eddystone was impossible. Not to be daunted, their Royal Highnesses determined on making another attempt to lay the foundation-stone, and the 19th of August was the second date selected for the ceremony, other portions of the work to the foundations being in the meantime proceeded with. Fortunately the weather proved more propitious on the latter occasion, the wind being moderate from the south-west, and the sea fairly smooth.

On the arrival of the Royal party at the rock, the dams had been pumped out, and the stone, weighing 3¼ tons, landed in readiness. A bottle containing a parchment scroll, with full details of the work, having been placed in a cavity under the bed of the stone, and the cement bed properly prepared, the stone was lowered into position, adjusted and bolted by the Master of the Trinity House, assisted by the Prince of Wales. The stone was then declared "well and truly laid" by his Royal Highness the Master. After this, favourable weather was experienced, and the work was carried on until the latter end of December, one hundred and thirty-one landings having been effected, work carried on for five hundred and eighteen hours, and one hundred and fourteen stones set in courses, 1, 2, 3, 4, 5, 6 and 7, being an average of 3·95 hours of work at each landing.

Work was again commenced at the rock in March, 1880, and rapid progress made. On the 17th of July, two years after the outset of operations, the whole of the cylindrical base was completed, and early in November, the end of the season, the 38th course of masonry was set. The weather setting in rough, work was then suspended until the following year. During this season one hundred and ten landings had been effected, six hundred and fifty-seven hours spent in work, and one thousand four hundred and thirty-seven stones set, the average number of hours of work per landing being 5·97.

Next season (1881) work was commenced in the middle of January. The top of the structure being well above the wash of the sea, the tools could be left behind and more rapid progress made.

As soon as the sixth room was completed, workmen were lodged in the tower, which further facilitated progress, since, during the absence of the steamer and working party, the central crane was lifted and adjusted, and things generally placed in readiness for the next day's operations. On the 1st of June, the Duke of Edinburgh, when passing up Channel in H.M.S. "Lively," landed at the rock, and laid the last stone of the tower. Thus the whole of the masonry was landed, hoisted, and set within two years. During this season forty landings had been effected, work carried on for two hundred and ninety-four hours, and six hundred and twenty stones set, being an average of 7·35 hours of work at each landing.

On the completion of the masonry a full complement of workmen were stationed in the tower to carry out the internal arrangements and fittings. The lantern was erected before winter set in, and early in the following year a temporary catoptric fixed light, consisting of twenty-four 21-inch paraboloidal reflectors and Argand lamps, was installed in the lantern of the new tower, and the light of the old one was discontinued on and after the 3rd of February, 1882. The optical apparatus for the upper and lower lights were meanwhile set up in the new tower. On the 18th of May the Duke of Edinburgh completed the work by lighting the lamps and formally opening the lighthouse. The edifice was thus completed within four years of its commencement, and one year under the time estimated.

The Author had opportunities during the previous winter of witnessing from the lantern of the new tower the action of heavy seas on the two structures. The waves, striking the old tower at its foundation, ran up the surface with great force, unimpeded by any projection until arriving at the lantern gallery, where they were partially broken up by the cornice, and then expended themselves in heavy spray over the lantern, entirely excluding from view, for the space of half a minute, any portion of the tower or lantern. It will be observed that this description closely resembles the illustration given on the title-page of Smeaton's narrative of the building of his lighthouse. At the new tower, the heavy seas striking the cylindrical base were immediately broken up, and rushed round to the opposite side, the sprays only ascending to the height of the lantern gallery.

During this winter an iron cannon, about 6 feet long, and 3 inches bore, weighing 10 cwt., was found at the base of the new lighthouse, having been washed up there from deeper water. It is supposed that this gun may have been one of those carried by the "Winchelsea," which was wrecked on the Eddystone rocks, shortly after the destruction of Winstanley's lighthouse.

The granite for the new tower was supplied by Messrs. Shearer & Co., of Westminster, from their quarries at Dalbeattie and De Lank. The blocks were delivered at the workyard at Oreston, dressed and fitted for the structure. On the completion of the solid portion of the tower, the supply from the Dalbeattie quarries was discontinued, and the whole of the remainder of the tower supplied from De Lank.

The Portland cement was supplied under contract by Messrs. Francis & Co., of Nine Elms. Sample briquettes having a sectional area of 1½ inch by 1½ inch, immersed in water immediately after setting, were required to stand a tensile strain of 350 lbs. after two days' immersion in water, 500 lbs. after four days, and 750 lbs. after seven days. So well did the manufacturers meet this condition, that none of the samples taken at random from the deliveries broke below the strains stipulated, and the average strain of the samples broken exceeded them by 16 per cent. The Roman cement for the brick cofferdams was manufactured from selected stone, and supplied fresh of excellent quality, as required from time to time, by Messrs. J. and T. Harvey, of Plymouth.

The Town Council and inhabitants of Plymouth having expressed a desire that Smeaton's Lighthouse should be re-erected on Plymouth Hoe, in lieu of the Trinity House sea-mark thereat, the Corporation of the Trinity House, who, as custodians of public moneys, had no funds available for such a purpose, undertook to deliver to the authorities at Plymouth, at actual cost for labour, the lantern and four rooms of the tower. These are now being re-erected by public subscription on Plymouth Hoe, on a frustum of granite, corresponding with the lower portion of Smeaton's tower, and it is to be hoped that it will ever be preserved by the town of Plymouth as a monument to Smeaton's genius, and in commemoration of one of the most successful, useful, and instructive works ever accomplished in civil engineering.

For taking down and shipping Smeaton's masonry, the upper portion of the iron crane used in the erection of the new tower, was fixed in timber partners in the centre of the upper rooms after the removal of the lantern, and the crane-post provided with a lowering and traversing jib. The taking asunder of the stones of Smeaton's work, in such a manner as to fit them for re-erection, was, as may readily be conceived, a very difficult and tedious operation. For shipment the "Hercules" was moored at about 10 fathoms westward from the rock, and the stones were taken on board with the aid of her machinery, by a process exactly the reverse of that by which the stones of the new tower were landed. On removing the stones of the gallery course, where the salt water had been driven through the joints of the masonry, previous to the reduction of the projection and the bolting down of the cornice in 1865, a thick deposit of salt was found on the upper surface of the cement bed of each stone. After the removal of the lantern and internal iron ties, and whilst the workmen were lodged inside the tower, a strong gale of wind and heavy sea from the westward was experienced. Such was the effect of the wave-strokes on the building, that a tumbler of water standing on the table in the living-room was thrown from it. After the removal of the structure to the floor of the lower room, the entrance doorway and well staircase leading from it to the lower room were filled in with masonry. An iron mast was fixed at the centre of the top of the frustum, and strong gun-metal cleats were let into the face of the tower for access to the top. It is to be hoped that the rock below will for ages endure to support this portion of Smeaton's lighthouse, which, in its thus diminished form, is still rendering important service to the mariner, in giving a distinctive character to the Eddystone by day.

It is a source of thankfulness to the Author to state that this dangerous work has been carried out without loss of life or limb to any person employed. He has further pleasure in stating that it has been completed at a cost considerably under the estimate of the Engineer-in-Chief. The total cost of the work has been £59,255, being £18,745, or 23½ per cent. below the estimate.

The low cost of this work is mainly due to the successful operation of the various mechanical appliances introduced by the Engineer-in-Chief for saving manual labour, and facilitating the progress of the work. Any comparison of its cost with similar structures which have preceded it in this country, can only be considered as approximate, owing to the ever-varying circumstances of each particular case. The Author has, however, submitted the table of comparative cost, furnished by Sir James Douglass in his Paper on the Wolf Rock Lighthouse,[1] to which he has added the new Eddystone and two other rock lighthouses erected since the Wolf Rock Lighthouse. From the Table it will be seen that the cost of the

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[1] Minutes of Proceedings Inst. C.E., vol. xxx., p. 28.

new Eddystone per cubic foot is lower than any similar structure yet erected.

Name of Structure.	Total Cost.			Cubic Feet.	Cost per Cubic Foot.		
	£.	s.	d.		£.	s.	d.
Eddystone (Smeaton) . . .	40,000	0	0	13,343	2	19	11½
Bell Rock	55,619	12	1	28,530	1	19	0
Skerryvore	72,200	11	6	58,580	1	4	7¾
Bishop Rock	34,559	18	9	35,209	0	19	7½
Smalls	50,124	11	8	46,386	1	1	7¼
Hanois	25,296	0	0	24,542	1	0	7¼
Wolf Rock	62,726	0	0	59,070	1	1	3
Dhu Heartach	72,584	9	7	42,050	1	14	6
Longships	43,869	8	11	47,610	0	18	5
Eddystone (Douglass) . . .	59,255	0	0	65,198	0	18	2

The Paper is accompanied by numerous drawings, from which Plates 1, 2, 3, 4 and 5 have been prepared.

[Discussion.

Discussion.

Mr. Douglass. Mr. Douglass called attention to a fac-simile of the lamp latterly exhibited at Smeaton's Tower, and to another of the lamps used at the new Eddystone Lighthouse.

Captain Sydney Webb. Captain Sydney Webb, Deputy-Master of the Trinity House, said he had been much interested in listening to the Paper, supplemented as it had been by excellent diagrams, enabling the members almost to follow step by step the very difficult undertaking that had been described. The Elder Brethren of the Trinity House were sorry to be compelled to face the question of the stability of Smeaton's tower; there had always been such a halo of romance surrounding it that it seemed a kind of sacrilege to demolish it. He was sure, however, that the members would agree with him that the present tower was a fitting successor to that of Smeaton's, and that in it the country had a lighthouse which, both as to construction and the power of its light, was of its kind second to none in the world. The new light was equal to 159,600 candles, as compared with 67, which was the power of Smeaton's original chandelier light, the cost per hour being about the same. The Elder Brethren were much gratified that the work had been so successfully accomplished. It was well known that great personal as well as moral courage was required in carrying out works of this nature, and although the Author had recorded the fact of its having been completed without loss of life or limb, he had said nothing of his own personal disaster when superintending the demolition of the old tower. When he was engaged in the work at a height of 70 feet, a portion of a chain guy of the sheers gave way, and striking him, hurled him from the tower to the rocks below. All his messmates thought that he must have been annihilated by falling on the rock, but at that moment a wave rose over the rock, and he fell on his side in about 3 feet depth of water, and was carried by the receding wave into deep water, where he struck out and was saved. Mr. Douglass came from a fine old stock. Captain Webb remembered his grandfather at the Bishop Rock Lighthouse when he erected it; and if his advice had been followed it would not have been necessary to strengthen the tower, as they were now doing, under his grandson's superintendence.

Mr. Owen. Mr. G. Wells Owen noticed the fact that, whereas in 1696 Winstanley erected the lighthouse represented in one of the

Mr. Owen. drawings, and in 1706 engineers had not arrived at the true lines on which to erect lighthouses, Smeaton in 1755 had discovered the correct principle of construction, which, as might be seen from the lines of the new lighthouse, had not yet been improved upon. He wished to ask the Author what effect the vertical base had had upon the action of the waves? It was stated in the Paper that in the case of Smeaton's lighthouse the waves rose rapidly until they struck the lantern. That, no doubt, would not be the case at the new lighthouse, but the question had occurred to him, whether the waves rising in the way described, would not ward off from the lighthouse the effect of the stroke of the water.

Mr. Redman. Mr. J. B. REDMAN was struck with the modesty of the Paper, descriptive of so grand and magnificent a work of engineering. All were familiar with the romance attendant upon the site in question. There had been three stages. First, Winstanley's lighthouse, like a Chinese pagoda stuck upon a rock, where the author, in his desire that it might be subjected to the most cruel gale that ever blew, experienced the fate he courted. Next, Rudyerd's tower, a combination of timber and stone, approximating somewhat in section to the outline of its successor, stood the fury of the sea for many years, and succumbed to fire. With regard to Smeaton's tower he thought it would be admitted that the Paper was a tribute to the remarkable genius of one of the greatest masters of their craft, more especially considering how limited were the advantages he possessed compared with those of his successors of the present day, not only in regard to education and training, but as respected improved mechanical appliances such as those which Sir James Douglass had so ingeniously adapted to the erection of an isolated structure in the sea. There were three marked differences between the present lighthouse and its predecessor to which he desired to direct attention. In the first place, the tower was so much greater in elevation and in cubic capacity, that its statical resistance to the sea must be enormously greater than in Smeaton's. Smeaton's tower stood upon the summit of the rock, and no doubt the site had been selected as being that where the greatest number of hours' work could be accomplished in one tide. There was a kind of recession or cavern under the base, and one of Sir James Douglass's predecessors, Mr. James Cooper, who afterwards became a partner with Messrs. Walker and Burges, was employed in supervising a gang of men in filling it in with solid masonry. On one occasion, in comparatively calm weather, a great undulation rose

Mr. Redman. entirely over the surface of the rock, and submerged the entire party. He believed they were all saved except one mason, who was drowned. The next point of divergence was the circular platform which Sir James Douglass had constructed, on the same principle as that which he had adopted in the case of the Basses Lighthouses, the curvilinear outline commencing at the level of high-water, instead of from the base, at the rock surface. No doubt that had the power of checking the rising water and its clinging to the tower, which was one of the defects of the old structure. The water ran up the tower and fell in a cascade over the lantern, completely obscuring the light—a difficulty which had been clearly surmounted in the present tower. A somewhat similar system had been adopted at the Menai Lighthouse in the level off-set courses of its base. The next point of difference was in the dowelling, which had been already described by Sir James Douglass in his description of the Bishop Rock. That system was invented by an old colleague of Mr. Redman's, the grandfather of the Author of the Paper, and it was no doubt an improvement upon the system of joggling and dovetailing adopted by Smeaton, which no one would now think of using. His courses were so worked that no one stone could be taken out without disturbing the adjoining stones. In fact it was one homogeneous mass, but very like a Chinese puzzle. The form introduced by the elder Douglass was more simple, but Smeaton's system of joggling and vertical connection by iron rendered him to a certain extent independent of the cement now used. The Douglass system, combined with the Portland cement of the present day, formed the most perfect mass. He should like to ask whether the large slabs of rock exfoliated from the windward surface were really the result of the leverage of the stroke of the sea upon the tower, causing the uprising of that mass of rock, or whether the occurrence would not have happened from constantly repeated wave impact if there had been no lighthouse upon the summit.

Mr. Beazeley. Mr. MICHAEL BEAZELEY could supplement Mr. Redman's account of the differences between the two structures by reference to the difference between the thickness of the two sets of walls. It would be observed in the design for the present lighthouse that a thickness had been adopted for the walls of the entrance chamber of 8 feet 6 inches, and a thickness of the top under the cornice of 2 feet 3 inches: the latter being the same as at the Wolf and the Longships. The thinnest part of the top of the walls of the new Eddystone was 2 feet 3 inches, whereas the thickest part of the walls

Mr. Beazeley. in Smeaton's tower was only 2 feet. If he remembered rightly, the curve was so slight in Smeaton's tower that, whilst the thickness of the walls below was 2 feet, the thickness of the part under the cornice was only 18 inches. It was curious to observe that the level of the solid parts in the two lighthouses were almost identical. A vast advantage had been gained by the increase of height in the new structure over the old one. Even putting out of sight the benefit derived from the circular base adopted by Sir James Douglass, he fancied it was almost impossible, at the increased height, for any water except spray to go over the lantern. There was an absence, however, in the new Eddystone, of the off-set courses customary in rock-lights ever since they were adopted by Mr. Walker at the Menai;[1] and Mr. Beazeley would like to ask Sir James Douglass whether there was any special reason for their discontinuance in the present structure. He believed they were originally adopted to break the force of the waves, and to prevent them running up the tower; also as an effectual water-stop to the lower beds, and to prevent the feathering away of the lower beds of the stone at the bottom of the curve. He could not help expressing his great admiration at the magnificence of the work, and the successful way in which it had been carried out without accident. With regard to lighthouses in China, he might mention that it had not been found necessary to erect them on rocks. In southern China, with which he was most familiar, having the charge of the lighthouses there, he scarcely knew any rock which required a lighthouse. All the outlying dangers were comparatively large islands, and those were nearly all lighted. The only lighthouse on the mainland with which he had been concerned was at Breaker Point. That was a wrought-iron tower, designed and prepared by Sir William Armstrong, and it was of a very novel description—a narrow cylinder of wrought iron stayed with stay-bars or rigging. There were several cast-iron towers (made in England and France), and of the remainder some were built of stone and others of brick with stone dressings. At Amoy a most excellent quality of brick was made, of which almost all the dwellings were constructed. The illuminating apparatus of the lighthouses in China was entirely dioptric, with one exception—at Chefoo, where it was catoptric. The greater number of lights of the first order in China were in the southern district, and many congregated in a small area.

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[1] Minutes of Proceedings Inst. C.E., vol. ii., p. 122.

Dr. Gladstone. Dr. J. H. **Gladstone** said he had of old taken great interest in the subject, and he had listened with great pleasure to Mr. Douglass's clear and interesting account of the modern improvements introduced in the new lighthouse. One of those improvements, which appeared to him to be a very great one, was the substitution of a flashing for a fixed light. Fixed lights were, perhaps, at one time all that could be desired; but now that there were so many fixed lights, and such bright lights in the vessels passing, it was necessary that each should indicate what light it really was; and that was obtained by the flashing apparatus described. He was glad that the periods were short. In the old revolving lights the periods were generally half a minute, or a whole minute, and frequently two minutes. That, especially during bad weather, was often a source of anxious perplexity to the mariner rather than an addition to his knowledge. The flashing light also was much brighter than a fixed light. In the case of a fixed light the rays were sent in a horizontal plane over the surface of the sea, but in the case of the flashing light not merely was that done, but they were gathered up into a powerful narrow beam which could penetrate to a great distance. That which previously illuminated, say 90° or 60° horizontally, was thus condensed within perhaps 5°. Another great improvement was that of the superposed lenses. He had not seen any lights of that character, but their advantages were obvious. When there was only one lamp, even though it were as broad as the one exhibited on the table, it might be obscured for the moment by spray or even by a bird flying (for birds were very much in the habit of flying towards lighthouse lamps), and various other causes, by which the mariner might be misled. With two lamps one above the other, with a series of lenses, that accident could scarcely happen, because the substance that obscured one light would not obscure the other. He could only express the great delight with which he had listened to the description of what were certainly great triumphs of engineering skill in the construction and illumination of a new, magnificent lighthouse in so difficult and dangerous a position.

Mr. Vernon-Harcourt. Mr. **Vernon-Harcourt** remarked that one point which had especially struck him was the cylindrical base, which would certainly be a great advantage in dividing the waves. No doubt it was true, as had been stated, that if the wave did not run up, it must strike a heavier blow; but it appeared to him that it was a great advantage that the wave should be so separated. Moreover, the blow would be dealt at a lower portion of the structure which, Mr. Vernon-Harcourt.

both by its position, size, and solidity, would be much better able to support it. The height of the lighthouse was also an important consideration, and it was quite possible that the spray which reached the lower light would not reach the higher one. A protecting dam and a cylindrical base were adopted, in 1878, at the Stannard's Rock Lighthouse[1] in Lake Superior. The dam, formed of cribwork weighted with stones, protected the inner iron casing, 62 feet in diameter, which was filled with concrete on which the tower was erected. In some American rock lighthouses the simple conical form has been chosen for the towers instead of a curved batter, as, for instance, at Minot's Ledge and Spectacle Reef lighthouses; and the same design had been followed at the Ar-Men Lighthouse[2] off the French coast; but possibly, in these cases, the restricted available area of the reefs might have led to the adoption of this form. The flashing arrangements appeared to be remarkably good. At the Casquets there were until 1877 three lights for the purpose of distinction, when one flashing light showing three flashes in quick succession, at periods of half a minute, was substituted, which was a simpler method of indicating that particular light. They were revolving lights, but the period was rather long. He certainly thought that short flashes had a decided advantage over long ones.

Mr. Price Williams.

Mr. PRICE WILLIAMS had had the privilege on several occasions of being present during the construction of the new Eddystone Lighthouse. The Author had stated that a great deal of the success and rapidity of the construction of the works was due to the mechanical appliances; and certainly anything more complete than the arrangements on board the "Hercules" it was almost impossible to conceive. He had especially noticed, at the early stages of the operations, the ingenious contrivance for pumping out water from the cofferdams, and also the arrangement of dividing them into compartments, so that a few minutes after the workmen got on the ground, and the pumps had been set to work, one of the compartments was ready. The contrivances for removing the stone from the ship's hold to the rock were admirably arranged, and the ship with its tramway on board was, in fact, a moving workshop. But what most impressed his mind, as a landsman, was the great apparent danger of the operations. There was exhibited a picture of the "Hercules" lying quietly moored near the rock; but he and his companions, who were landsmen, realized a very different idea when they were there. He often

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 353.

[2] Ibid., liv., p. 307

had misgivings when he witnessed the risk the men were running, and when it seemed that every wave was about to overwhelm them. But such was the discipline and the courage of the men, and such was the admirable way in which Mr. Douglass managed affairs, that he recognised on the first day, not only that the men were skilful in carrying out the engineering works, but that they were first-rate sailors. Those who were in command were always ready to share the danger; they carried their lives in their hands; wherever there was danger Mr. Douglass or his father was found on the spot. The Author had expressed his thankfulness that no fatal accident had happened. One ground of his thankfulness was his having so providentially survived the terrible accident to which reference had been made. With regard to the influence of the cylindrical base on the wave-stroke, he had noticed that the effect produced by it in breaking up the waves was enormous. Mr. Price Williams.

Mr. JAMES C. INGLIS said it was a matter of common knowledge before the new lighthouse was commenced that the vibrations in the old tower were considerable. The lighthouse-keepers had told him of various articles in the cupboards and elsewhere vibrating. He should be glad to hear whether any such vibrations had been observed or not in the new lighthouse. He had wished to see the mortar of which the old lighthouse was composed, and he had been surprised to find that many parts of it could be crumbled with the fingers; he would ask whether the excessive vibration had anything to do with that peculiar condition. Perhaps it might have arisen from the mortar having been so long exposed to the atmosphere. He had remarked the very superior character of the stonework in the new compared with that of the old structure. The joints in Smeaton's tower were $\frac{3}{8}$ to $\frac{1}{2}$ inch thick; in the new lighthouse they were $\frac{1}{8}$ inch, or perhaps less. It would be interesting to have some information as to the mortar, because evidently the old lighthouse, thin as it was, had to depend to a great extent for its stability on its weight. There was another point which he desired to mention, as being one in which people in the West were greatly interested; namely, the connection of the old lighthouse with the shore — not so much for commercial facilities as for giving information of ships in distress and requiring assistance—information which was received in Plymouth in a very desultory, uncertain, and haphazard way. It appeared to him that as the new lighthouse commanded an enormous expanse of water, it might be made useful in affording such information; at any rate the public would like to know what reasons there were for the telegraphic communication not being completed. Mr. Inglis.

Sir Robert Rawlinson.

Sir ROBERT RAWLINSON, C.B., supposed Sir James Douglass considered that there was great advantage in the vertical face in the lower part of the lighthouse tower in stilling the rise of waves. He wished to ask Sir James if he considered a second or a third tier of vertical faces would have been any detriment or any advantage to the lighthouse. In Sir Robert Rawlinson's opinion, it would have been an advantage. Waves of motion were brought to rest by a vertical face much sooner than by a sloping face; and if a sea-wall had to be subjected to the greatest possible wear and the greatest possible action of the waves, it would have a sloping face. He also wished to ask Sir James Douglass if he thought that the joggling of the joints of the ashlar represented on the plans was an advantage or not. It apparently locked the stones; and he assumed that it was done to prevent their moving. For himself, he did not see any advantage in the joint joggling. The old master under whom he was brought up, Mr. Hartley, in the commencement of his career caused ashlar masonry to be worked as perhaps no engineer ever caused it to be worked before. He tried "dodges" with it, putting raking beds against the heels of the hollow quoins upon curves. It was a difficult piece of masonry to produce, but he abandoned it in his mid-career as not serving any practically useful purpose. Masonry must depend upon gravity for its stability, and not upon any form of joggling to hold it together. There was a precedent for the joggling adopted by Sir James Douglass, because every course of Smeaton's lighthouse was not only joggled, but was dovetailed more elaborately than in the present lighthouse, since the courses were dovetailed into each other as well as being both joggled and dowelled. He had never been engaged in the construction of a lighthouse, but in his younger days he had made full detailed drawings of the Rock Lighthouse at Liverpool, which was an exact model of the Eddystone lighthouse. He therefore knew something of the construction of a lighthouse, and of the difficulties that had been overcome by Sir James Douglass. The younger members of the Institution, who had not had much practice in their profession, could scarcely appreciate from the mere reading of the Paper, the difficulties that had been encountered and overcome. The credit due to Sir James Douglass in mastering those difficulties was very great, and the title which Her Majesty had been graciously pleased to confer upon him was but a fitting reward for the ability he had displayed. Let them imagine that they had to work in a rough tideway, and to begin the construction at or about low-water; that they had to fight with moving

Sir Robert Rawlinson.

water in every stage of progress, and to continue the work even when it was almost as much as could be done to keep the boat at her moorings, going on as it were stealthily, stone by stone, getting the material to the site, and raising it gradually into position. The rapidity with which the work was done under those circumstances was, he thought, almost unprecedented. The members had heard the lowest estimate sent in by contractors who were supposed to know their business, and they had also heard the sum at which Sir James Douglass had completed the work carried on by the untiring energy and ability of his son. He was sure that Sir James Douglass would not consider that he was casting any discredit upon his constructive ability, by asking him if he considered that the joint joggling was necessary, or that it gave additional strength? There should be neither bent-beds nor mitre-joints, and it should be clearly understood that no form of rusticating added strength. Arch-stones were wedges, that was, the beds should be true planes to the radius line of the arch. The stability of an arch must depend upon the resistance of the abutment and the true balance of the stones forming the arch, and not on bent-beds, joggles, dowels, or any other device or trick in construction. A graceful, well-proportioned and well-balanced bridge was the perfection of masonry.

Mr. Brunton.

Mr. R. H. BRUNTON said it had been remarked by Mr. Beazeley that the Chinese had erected a number of iron lighthouses, which had "been made in England." He should be glad to know why they had been obtained from England, because in Japan several cast-iron and wrought-iron lighthouses had been erected which, with one exception, had been made by Japanese artificers, and the Chinese artificers in this class of work were equal, if not superior, to the Japanese. The Japanese not only made their own lighthouses, but the lanterns and the lamps, and even the plate-glass used in them. They did not yet make the dioptric apparatus, which they obtained from Paris. There was not now a single European in the employment of the lighthouse department of the Japanese Government. Probably, if Mr. Beazeley did not wish to share the fate of the Europeans formerly employed in Japan, he would still get everything he could from England. There appeared to be two points of novelty in the construction of the Eddystone lighthouse, the circular base, and the superimposed lenses. It had been said that the green seas rushed up Smeaton's tower to the cornice and considerably above, and that, in the case of the present tower, the circular base broke the waves which rushed round to the opposite side. If that were so, it appeared that the energy expended in projecting the volume of water, say 50 or 100

Mr. Brunton. tons, so many feet into the air, was now expended directly against the circular base. Of course the question came to be, whether the present tower had the statical resistance necessary to withstand that enormously increased force. With regard to the superimposed lenses, he should like to ask if the arrangement was intended as one of the first examples of the surrender of the principle of focal compactness, because certainly there was not a large focal compactness in two burners, of seven wicks each, in one lighthouse-lantern; or whether the theory of volume of light, as distinct from intensity, had not to some extent led to the adoption of these lenses? Before Fresnel introduced his system the size of the flames was the only thing on which the efficiency of the lights depended; but after Fresnel all efforts of lighthouse-engineers were directed, first, to the construction of an apparatus which would catch every possible ray; and, secondly, to the reduction of the focus as nearly as possible to its theoretical dimensions, namely to a point. It might be that lighthouse-engineers had ridden that hobby a little too far, and that a reaction was setting in; and he thought that the adoption of the superimposed lenses was an indication of that reaction. The doubling or quadrupling the size and the power of the light was carried out, this involving an enormous loss of light. With regard to the amount of loss, he had seen in a published despatch of the Trinity House to the Board of Trade, a statement that it was 12 per cent.; that, he thought, required a little explanation, which perhaps Sir James Douglass would give. In the Paper the maximum light of the unassisted flame in the new Eddystone was given as 1,900 candles, and the intensity of the beam from the apparatus was 159,600 candles, an increase of 84 times. With an octagonal complete revolving apparatus the increase was calculated at 250 times. From a twelve-sided apparatus, such as the one exhibited, the increase might be calculated at about 135 times. The increase given by Sir James Douglass being only 84 times, there was a loss of 37 per cent., and that agreed with what might be concluded from the apparatus itself. The refracting portion of a complete apparatus subtended an angle of 145°; the lenses in the new Eddystone subtended, according to the Paper, an angle of 92°; so that about 80 per cent. of the light was acted upon by a complete apparatus, whereas only 50 per cent. was acted upon by the new lenses; showing that there was a loss of 30 per cent., or rather, that 30 per cent. fewer of the divergent rays were parallelized by the new lenses. One other point required a little explanation. The maximum light of the new lenses, as given in the Paper, was 159,600 candles, which was said to be 23·3 times that of the old Eddystone lighthouse: 159,600, divided by 23·3, would give 6,850 candles. Assuming that there was an old four-wick lamp in the old lighthouse, affording light equal to 300 candles, there was only an increase of about 23 times. Perhaps Sir James Douglass would explain what sort of apparatus was used in the old Eddystone, giving that small increase. He thought that the discussion of Sir James Douglass's Paper on the Electric Light applied to Lighthouses showed pretty clearly the correctness of the theory which Mr. Brunton had mentioned some time ago,[1] that volume of light was more important than intensity to penetrate a thick atmosphere. The reason given by the late Sir William Siemens had never been contradicted, that the violent agitation of a few particles in the atmospheric medium was more easily arrested by thick weather than the less violent agitation of a great number of particles; and if that was correct, it appeared to be quite plain that much of the ex-focal light served a definite purpose in putting into a state of vibration a larger area, and so resulting in its continuation to a greater distance. He thought, therefore, that focal compactness was a thing not to be too much strained after, and that Sir James Douglass had been quite right in adopting the incomplete apparatus which he had used in the new Eddystone. He had recently seen a remark made by the late Sir George Jessel, that if a person had conceived a new principle, or a new idea, with regard to art or manufacture, and then showed a way of carrying it into practice, he might patent that method, though he could not patent the idea. That appeared to be a very good indication of an excellent rule for engineering practice. Engineers might, without great impropriety, adopt the ideas of other people, if they were ideas only, but they could not very well, without proper arrangement, adopt ideas, which possibly at the expenditure of much time and labour, had been reduced to practice by other persons. Many people had thought of using mineral oil in lighthouses, but Captain Doty was certainly the first to put it in practice. Many persons also might have thought of using superimposed lenses in lighthouses, but Mr. Wigham was the first to show the practical utility and advantage of the method. He could only say that in his opinion the Trinity House mineral-oil burner, the superimposed lenses in the Eddystone Lighthouse, and the gas-lamp on the table were standing examples of an infraction of that salutary rule. Mr. Brunton.

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[1] Minutes of Proceedings Inst. C.E., vol. lii., p. 78.

Mr. Barry. Mr. J. WOLFE BARRY asked whether the cost of the work quoted in the Paper included the cost of the plant—the hire of the steamer, rent of wharves, and all the other matters which went to make up the total cost of the structure? No doubt, in making comparisons of the cost of various lighthouses, every allowance should be made for difference in expenditure under different conditions; but it would be interesting to know whether all the items to which he had referred had been included in the quoted price per cubic foot, which had struck him as being very small considering the great difficulties, labour and risk of such a work. He also wished to ask the reason for the selection of the height above high-water spring-tides which had been adopted for the cylindrical base? At first sight it would appear that heavy seas at high water would overtop the cylindrical part and cause damage, and he should be glad to know from Sir James Douglass whether the height chosen had been found sufficient, or whether he thought that it would be advisable in future structures to raise the cylindrical portion to a higher level.

Mr. Allam. Mr. E. C. ALLAM thought that the adoption of a cylindrical base by Sir James Douglass was a wise departure from the Smeaton model—a model which, up to the time of building the Great Basses Lighthouse, had, he believed, been followed in every case of the erection of a rock lighthouse-tower. A rock lighthouse-tower was subject to two destructive forces, those of the winds and of the waves. Smeaton had observed that he conceived the idea of the form of his tower from the trunk of an oak. If a lighthouse-tower was, like an oak-tree, subjected only to the force of the wind, that form would be perfect; but in point of fact there was no analogy between the two cases. In the case of the oak-tree the overturning force was exerted almost entirely at the top, and in the case of the lighthouse it was exerted almost entirely at the base. The force of the waves, too, was so far in excess of that of the wind that the latter might be practically disregarded; for, if a lighthouse-tower was strong enough to withstand the force of the waves, it would certainly be strong enough to withstand the force of the wind. A lighthouse-tower might be destroyed in either of two ways, either by being moved bodily by the sliding of the base upon its foundation, or by being fractured at some point in its height, and the upper portion being overthrown. In the generality of cases it was so easy to guard against the first mode of destruction by sinking the tower into the solid rock, as in the case of the new Eddystone, that the attention of engineers should be mainly directed to the question of destruction by the second method. A wave advancing against

Mr. Allam.

and being checked by such an obstacle as a lighthouse-tower, had two courses open to it: it might either divide, and, forcing aside the mass of water on either hand, pass at once to the rear, or it might rise up the face of the tower. If the diameter of the tower was comparatively small, and the face perpendicular, it would generally be found that the wave would take the former course; if, however, but a slight inclination was given to the tower there was a tendency in the wave to rise up the face. The tower that had the most spreading base with which he was acquainted was that of the Bell Rock Lighthouse, and this climbing action of the waves was there well illustrated, as shown in Turner's celebrated picture of "The Bell Rock Lighthouse during a storm." In his opinion that form of tower was wrong in principle. To divert the wave from the solid base where it was best able to withstand the shock, to cause the base, as it were, to shirk the duty which it was so well able to perform, and to send the wave aloft to strike against the less solid portion of the tower, seemed to him like the action of a commanding general who allowed the enemy to break through the front ranks of his army where his veterans were stationed, and fall almost unchecked on the recruits in the rear. With reference to the disintegrated condition of the mortar in the old tower, he should like to ask Sir James Douglass what connection he considered existed between that state of things and the vibrations noticed in the tower, whether the vibrations caused the disintegration, or whether the decay of the mortar had anything to do with the insecure condition of the tower itself? It seemed almost sacrilege to hint even at any imperfection in Smeaton's Eddystone, but it was in no sacrilegious spirit that he asked the question. He had been up Smeaton's other tower, that at Spurn Point, when, to use the expression of the keeper, "it was rocking like a ship's mast," although the diameter of that tower was very large in proportion to its height. In that case, however, the oscillation was not produced by any instability in the building itself, but resulted from the elastic nature of the sandy foundation on which the tower was built. It was a cause of universal regret that the necessity should ever arise for taking down Smeaton's tower, but that necessity having arisen it was satisfactory to know that it had been superseded by such a fine structure as the present lighthouse. With regard to the Douglass lamp now being introduced into the Eddystone and other lighthouse-towers, he could only say that if such a light as that exhibited on the table could be produced from either gas or oil, Electric-light engineers would have to look to their laurels. While

Mr. Allam. thanking Mr. Douglass for his excellent Paper, he thought with their thanks the members ought to join their congratulations upon his providential escape while carrying out so difficult and dangerous a work.

Sir James Douglass. Sir JAMES DOUGLASS desired to unite with the Author of the Paper in his expressions of thankfulness that the work had been carried out without the loss of a single life. It was also a great satisfaction to him to know that it had been carried out somewhat below the sanctioned estimate, a result largely due to the able assistance he had received from his staff at Trinity House, and on the works, also to the earnest zeal of all the men employed at the work. Every man was eager and zealous in following their leaders who always acted on the example of their noble craftsman, Smeaton, in being foremost at the post of danger and honour. He was quite sure that every man who had been employed at the work would to the day of his death consider it a glorious privilege to have been permitted to assist in it. He mentioned the circumstance because it showed the importance of engaging the earnest sympathy of all the men employed in a work of that kind. The number of men was necessarily limited, and unless every man was willing and determined to do his duty, success could not be expected. He desired also to record thanks to the contractors for the granite, Messrs. Shearer and Company, for their excellent material and workmanship, and for their having completed the work six months within the specified time. He had great pleasure in making that acknowledgment, because in his experience it was very uncommon to find a granite contract completed within the time. It might be desirable to say a few words with regard to his deviation from the curve adopted by Smeaton for such a structure. The question of arresting the force of a large ocean wave on a structure of that kind had long engaged his attention, and he had come to the conclusion that for heavy seas the only form to be adopted for a lighthouse-tower was a cylindrical base. It was true that it received a heavier blow on the curved surface, but the blow was delivered at a point where the structure was best able to receive it, and at the point of least leverage, and thus of least destructive effect on the rock-foundation below. Mr. Beazeley and Sir Robert Rawlinson had referred to small stepping, contrasting it with the large stepping or cylindrical base. The stepping of each course of the masonry was adopted by the late Mr. James Walker, Past-President Inst. C.E., in 1834 at the Menai lighthouse, and it was no doubt the right method where small waves were dealt with. There were examples of the small stepping at

Sir James Douglass.

the Bishop, Wolf, and other rock lighthouses, but it was found that the effect was very feeble in arresting the upward trend of a very large wave; indeed it was little more than might be obtained from a roughened surface of the curve of Smeaton., With the large cylinder the wave was immediately divided, and prevented from rising, which was very important in the case of a lighthouse, because the first consideration should be to prevent the sea from reaching the lantern and impairing the distinctive character of the light. There was also another important consideration, namely that of arresting the heavy stroke of the falling wave, and preventing, especially where the rock was soft, injury to the foundation below. He would prefer that the downward stroke be received on the masonry, forming as it did a piece of solid granite, rather than upon a doubtful piece of rock below, as at the Eddystone. With regard to the effect of the sea on the Eddystone, the diagram, rough as it was, fairly represented the actual state of things. The Author in the original diagram had shown the appearance of the sea as observed from the new tower during a heavy gale, and Sir James Douglass had since added a representation of the appearance of the sea as given by Smeaton in his narrative. It should be remembered that in the one case the sea in a gale was represented where the lighter portion of the crest of the wave was broken up and driven to leeward by the force of the wind, while in the other case it was, as Smeaton stated, on the morning after a storm, when the waves rose higher on the tower, and fell nearly perpendicularly on its lee side. He could bear testimony to the correctness of the diagram. He had been on one occasion detained three weeks in the tower during stormy weather, and he had the opportunity of observing both heavy ground seas without wind and heavy seas during storms. He was much amused when the first storm came on by the keeper on watch telling him that he must wedge up the shutter of his bed-berth if he wished to sleep. He found attached to the shutter by a lanyard the required wedge, but he first tried to sleep with the shutter rattling with every wave-stroke on the tower; finding this impossible he was compelled to apply the wedge, when he managed to sleep soundly. He spent much of his time in watching the seas, and reading the excellent books provided by Trinity House; the time passed very happily, and he believed with profit. With regard to the dovetailing or joggling, he considered that in such a work it was of very great importance. It did not add materially to the cost of the structure, but it added immensely to the reliability of the work step by step as it was carried on, and thus facilitated its construction.

Sir James Douglass. He did not know any other system by which it was possible to set masonry with such readiness where exposed to heavy seas. By the method adopted each stone was supported not only by the stone below, but by the stones that were beside and behind it, so that it could be left immediately after setting with perfect certainty. They had never lost a stone there; a few were lost at the Wolf, but there was every reason for concluding that they had been struck by wreckage. From that point of view alone he was quite certain that the system was worth the money expended on it; but in addition to this a complete water-stop was provided at each bed and joint, and it rendered the work a perfect monolith. He did not believe that it was possible to procure from any of the granite quarries of this country a mass of granite of the same dimensions more perfectly homogeneous. Another point was the security given by the system to the walls, with the strain imposed upon them by the system adopted of erection by steam-machinery afloat. Had not the work been put together in the manner described they could not have ventured to take lifts from the steamer with rough water as they did. With reference to the question of luminaries, it was evident that no lighthouse could be considered as completely fulfilling its functions unless it was provided with a good light. His attention had been directed to this question for many years, and always in the direction of condensing flame-luminaries to the utmost possible extent. The model exhibited was of the Fresnel burner with its flame 3⅜ inches diameter and 4 inches high. That flame was carefully calculated by Fresnel for application in his optical apparatus of the first-order dimensions, at 920 millimetres focal distance, so that the vertical divergence where the rays of maximum intensity were sent direct to the sea-horizon, should just be sufficient to illuminate the sea from the horizon to the shore without waste. It was also so calculated in its diameter as to be utilized with the greatest possible economy for flashing lights, of the required length of flashes of one-quarter minute, half-minute, or one-minute periods. The flame-luminaries of Fresnel were also proportioned to the six sizes of apparatus, from the four-wick burner down to the single wick. Sir James Douglass had therefore worked in the direction of raising the initial intensity of the flame-luminaries for first-order optical apparatus without unduly increasing their dimensions. In the Eddystone burners he had doubled the focal dimensions of the flame, but he had raised the intensity from 269 candles to nearly 1,000, so that he had more than doubled the initial intensity per square inch of the focal area of the luminary. It was true that there was less economy in using such a flame with

Sir James Douglass.

the first order apparatus, but there was a higher intensity in the resultant beam, and the flashes were somewhat prolonged, which generally satisfied the mariner. On the other hand, with regard to the vertical divergence, there was more in-shore illumination, which was also an advantage. But while the utmost had been done for oil- and gas-flames, what had occurred with regard to the electric light? When comparing the initial intensity of flame and electric-arc luminaries, it was found that where the electric arc was applied they had 200 times the intensity per square inch of focal area of that of the best oil- or gas-flame. He thought there could be no better proof than this of the immense value of the electric light in the focus of optical apparatus for penetrating a thick atmosphere. He might be permitted to say a few words on the subject of penetration. When on the 8th of December, 1858, Holmes installed his electric light at the South Foreland, it was seen that greater distances would be penetrated through fog than had been previously considered to be possible. Since that date there had been a spirited rivalry between oil- and gas-flames and the electric light, and that had in a great measure led to the flames exhibited. It might be well to review what had occurred at the Eddystone since Smeaton's time. Smeaton's 67-candle light was sufficient to reach the sea horizon during clear weather, 14 miles distant, but unfortunately on the English coast, especially during winter, clear weather was the exception and not the rule. Taking an instance where the present light was just visible at 14 miles, in such a state of atmosphere Smeaton's 67-candle unit light would reach only 4 miles. In another case where Smeaton's light would just be visible at 1 mile, a distance that could now be covered by a sound signal, the present light would penetrate 3½ miles, and if electricity were to be applied in its present condition of maximum intensity with reliability, another mile would be added. Looking at electricity from that point of view, it was very satisfactory to know that it was not only the most powerful luminary, penetrating the greatest distance for coast-light purposes, but that it was per unit of light provided the cheapest. Under the circumstances referred to, the cost would be about one-third that of gas and about one-half that of mineral oil. Mr. Brunton had referred to some remarks of Sir William Siemens. Sir James Douglass was glad to be able to remember some other words of Sir William Siemens, uttered in that room on the evening of the reading of his Paper on "The Electric Light applied to Lighthouse Illumination," words which appeared to be quite different from Mr. Brunton's recollection. With regard to the ques-

Sir James Douglass. tion of focal compactness of light "it was true that Mr. Wigham had said he liked his light ex-focal, in order to give a glare; but Dr. Siemens apprehended that few persons would coincide with Mr. Wigham in that view. It might be an advantage in looking at a light at a short distance, but the ex-focal light would give very little effect at a great distance."[1] That view must be endorsed by any man who was acquainted with the practical application of a powerful luminary in an optical apparatus. With reference to the items of cost, the Secretary of Trinity House was present, and would be able to endorse anything that had been stated by the Author of the Paper upon that point, and to testify to the correctness with which the accounts of Trinity House were kept. He might say as their Engineer, that he had been taxed with every farthing fairly chargeable to the work as it progressed step by step, including the cost of the plant. With reference to the question put by Mr. Barry in regard to the height of the cylindrical base, he believed that the summit of the base was at about the right position for the Eddystone. With no heavy sea rising to the upper part of the tower he believed that its statical resistance would be sufficient to meet everything going against it. It was found that there was scarcely any perceptible tremor in the structure. The chief consideration with regard to the base was its convenience as a landing platform on all sides, and if it had been unnecessarily raised it would have been rendered inconvenient in that respect. If the lighthouse had been further westward, say off the Scilly Isles, with heavier seas than at the Eddystone, he should certainly have raised the cylindrical base higher, possibly 8 or 10 feet.

Mr. Douglass. Mr. W. T. Douglass in reply upon the discussion stated that he had been favoured with a communication from Sir George Airy, Hon. M. Inst. C.E., who had devoted much attention to wave-action, relative to the cylindrical form of base adopted for the new Eddystone, in which he fully concurred. Sir George Airy, however, expressed some fear that the water might be driven into the joints below the coping stones of the cylinder, and that it might exercise an almost irresistible force in lifting these stones. His own opinion was, considering the manner in which the work was dovetailed and cemented together, that it was an impossibility that any such damage could occur, unless the work was struck by floating wreckage, impelled by a heavy sea. The mortar of the old tower throughout the portion of the masonry that was removed, was uniformly hard and tough. On lifting the stones

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[1] Minutes of Proceedings Inst. C.E., vol. lvii., p. 156.

Mr. Douglass.

forming the lantern gallery, which had been previously loosened from time to time, and where the sea had been occasionally driven through the beds and joints, a thick deposit of salt was found on the upper surface of the cement beds, yet the mortar even here showed no sign of deterioration. Some samples of this mortar were laid on the table for inspection. The effect of the vibration and leverage of Smeaton's tower upon the rock-foundation, in facilitating disintegration, was manifest from the fact that fractures had occurred in the rock directly across the line of direction of the laminations, and where the rock had previously been sound. Referring to the suggestion that the ideas of others had been adopted at the Eddystone, he considered it difficult to conceive how an engineer could possibly design and execute any important work in all its details on entirely new ideas, and he was not aware that such an impossibility has been suggested in the Paper. With reference to the employment of superposed lenses, he had given an historical *resumé* of their development, from which it would be seen that the idea was not that of Mr. Wigham, neither was their first application due to him, for he should have stated that this was due to Professor Holmes, who introduced superposed lenses for the electric light at Dungeness Lighthouse in 1862, and they were afterwards adopted by Mr. E. Allard, director general of the lighthouses of France at La Hêve Lighthouse[1] in 1863. He had clearly shown by the diagrams that the method followed at the Eddystone differed entirely from Mr. Wigham's. Again, coal-gas and mineral oil had been in use as lighthouse luminaries for many years before gas was suggested by Mr. Wigham, or mineral oil by Captain Doty. Coal-gas was first employed in this country for coast illumination in 1827, at the Troon Lighthouse which was also the first Lighthouse where provision was made for increasing the amount of light during thick weather, fifteen gas-jets being ordinarily employed, which were increased to twenty-five during fogs. Mineral oil was first used in the French lighthouses about the year 1860, and at the Lune lighthouses in this country in 1869. Further he had shown by the diagrams and models, that the burners of Sir James Douglass, both for coal-gas and mineral oil, differed entirely from those referred to by Mr. Brunton.

By the kindness of the Elder Brethren of the Trinity House he was enabled to exhibit the clock originally placed by Smeaton in his tower on its completion, and which was still in efficient

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[1] Minutes of Proceedings Inst. C.E., vol. viii., plate 3.

Mr. Douglass. working order. Smeaton stated in his narrative (p. 170), "A time-piece I had provided was set up and put in motion. This time-piece by a simple contrivance being made to strike a single blow every half-hour, would thereby warn the keepers to snuff the candles."

Correspondence.

Mr. Mosse. Mr. J. R. MOSSE remarked that, through the courtesy of Mr. William Douglass, M. Inst. C.E., who was then constructing the Great Basses Lighthouses, Ceylon, he visited the works in 1872. Although workmen had landed on the rock that morning, the sea subsequently rendered landing impossible, and he had therefore to watch the process of landing the stones from the screw-steamer "Hercules," which was moored broadside on to the Basses rock. As described in the Paper, the stones were raised from the hold of the vessel by a steam-winch placed forward of the hatchway, and to the stone another chain was attached, which, after passing through a block fastened to a derrick on the rock, was wound round the steam-winch near the stern of the steamer. As the former winch slackened the stone was hauled by the latter winch through the water, and landed by the derrick on the rock; the whole process occupying some five or six minutes for each stone. Nothing could be neater, more simple, or satisfactory than this system. As regarded the height of the vertical circular base, he presumed it should depend upon the height to which the crest of the waves rose in storms, so that the main force of the water might be broken on the base, rather than on the tower, up which the waves would otherwise rise. Probably to utilize the masonry prepared for the proposed "Gordon" Lighthouse, the height of the vertical base of the Great Basses Lighthouse was about 32 feet above high water.

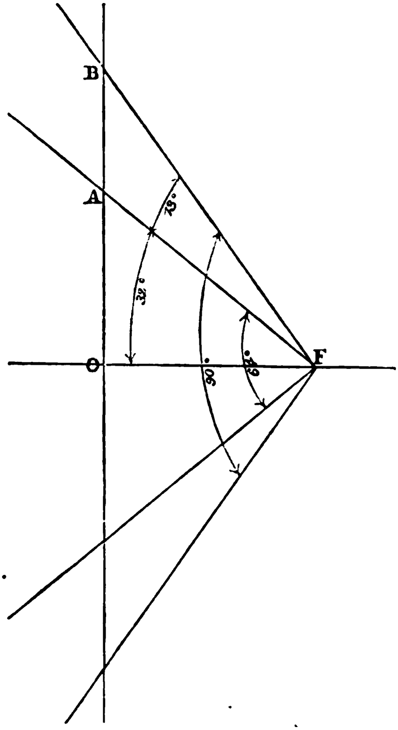
Mr. Wigham. Mr. JOHN R. WIGHAM observed that the Paper had been of peculiar interest to him, both from his long connection with lighthouse matters, as also from the fact that he had the pleasure, in company with the Author, of visiting the new lighthouse-tower, and of standing upon the old one, and looking at the Author's admirable arrangements for demolishing Smeaton's great work. He had much pleasure in acknowledging the great courtesy and kindness of the Author during the visit. A finer structure than that of the new Eddystone did not exist; and the details of every part, down to the most minute particular, were such as to command admiration. The portion of the Paper upon which he desired

Mr. Wigham.

chiefly to comment was that which referred to the optical apparatus. The Author stated that there were two superposed tiers of lenses (biform), twelve panels in each tier, and that "these lenses subtend the largest vertical angle of any yet constructed for coast-illumination." He presumed that in this statement the Author referred to the combined effect of the tiers of lenses, and if so, he thought he had fallen into an error; for the quadriform lenticular apparatus at Galley Head, which Mr. Wigham had constructed, was 12 feet 5 inches in height, and this gave a vertical angle to a trifling extent greater than that of the Eddystone, the focal distance being the same in both cases. The advantage of quadriform (four lenses) over biform in such cases was, however, very great. Quite irrespective of the obvious fact that the rays of light which reached the top and bottom of the long biform lenses must necessarily lose much of their power from the obliquity with which they fall on the glass, there was the much more important and still more obvious fact that the intensity of the light from four burners was much greater than from two. The figure illustrated the first of these reasons. It was evident that in the angle B F A the luminous ray fell upon the face of the lens B O at a much more acute angle than that of A F O, and therefore there was a portion of the light which was reflected instead of being refracted. But the main superiority of the quadriform over the biform lay in this, that the best part of the four lenses, namely, the parts nearest to the focal flame, were directly exposed to the full blaze of each of the four flames used with them. Professor Tyndall, in a recent letter on this subject, stated that, had even a triform apparatus, instead of an elongated biform, been erected at the new Eddystone, in less space and probably at less cost, 40 per cent. would have been added to the power of the light.

The Author went on to say: "Various combinations of superposed optical apparatus have been employed in lighthouses since the application by Faraday in 1843 of ventilating tubes to each lamp, for conveying to the cowl of the lantern the products of their combustion." Inasmuch as Faraday's tubes had reference to dioptric apparatus, he thought the Author was here mistaken; only one central oil light was ever used in dioptric apparatus, and he was not aware that there had been any application of superposed lenses, till in 1877 the quadriform gas apparatus at Galley Head was lighted; and this was borne out by a statement of the Author that at Galley Head was the first application of superposed lenses with gas-flames, and that at the Eddystone was the first

Mr. Wigham. with oil as the illuminating material. The Author observed that Mr. J. W. D. Brown proposed superposed lenses so far back as 1859; but that gentleman never gave any description of his plan, nor was it ever put into operation. The Author further stated that Messrs. Lepaute and Son, a year previous to the introduction of superposed lenses at Galley Head, made successful experiments with this method of placing lenses, but as Mr. Wigham's patent, under which Galley Head was lighted, was dated 1872, he had evidently preceded them in this invention. He only mentioned this fact because, unfortunately, he was at present engaged in a controversy with the Elder Brethren of the Trinity House on this very subject, claiming that they had infringed his patent in fixing the superposed oil lights at the new Eddystone. He would not go any further into the question than to say that in his patent specification oil was specially mentioned as one of the sources of illumination referred to in the invention. The lamps, burners, and flues at the new Eddystone Lighthouse were



Mr. Wigham.

most ingeniously constructed, but to his mind they were defective in one important particular; the flues for conveying the products of combustion from the lower lamp obstructed the light from the upper lamp in three places, so that, as the lenses revolved, the light from the lamp to the best portion of each lens, as well as every other portion of it in its turn, was obstructed by these flues. No doubt each flue was flattened, so as to reduce to a minimum the obstruction of light; but, as he had recently pointed out to the Commissioners of Irish Lights, in a case where it was proposed to use two oil lights after the fashion of the Eddystone, there was no necessity that these flues should ever interpose between the burner and the lens. Now, as to the burners at the Eddystone, the Author stated that they were of 720 candle-power, but that it was proposed shortly to increase their intensity to 950 candles, and further on he claimed an intensity of nearly 1,500 candles, by an improved burner not yet put into use, which he described as "the most efficient burner yet produced for any illuminating oil or gas." This statement was surprising, for some years ago it had been demonstrated by Mr. William Valentin, of the Royal College of Chemistry, South Kensington, in the presence of Sir James Douglass and himself, that the illuminating power of the largest gas burner used at Haisbro' Lighthouse was 2,923 candles. Two such lamps would, of course, give a light equivalent to 5,846 candles, which was much greater than 1,440, the combined light of the two lamps of the Eddystone, or even 3,000, the combined light of the two improved lamps to which the Author referred, but which had not yet been practically used at the Eddystone or any other lighthouse. The illuminating power of the lamp when increased by the optical apparatus was stated by the Author to be 159,600 candles; but this was a feeble light compared with the quadriform apparatus at Galley Head, which was calculated to transmit to the horizon a light equal in strength to 1,090,000 candles, and this from burners each of which had only an illuminating power of 1,253 candles.

Mr. Douglass.

Mr. W. T. Douglass, in reply to the correspondence, observed that the collective height of the two superposed tiers of lenses at the Eddystone was about the same as that of the four tiers of lenses adopted by Mr. Wighamat the Galley Head Lighthouse; but with the important difference that at the Eddystone, only two luminaries were employed, while at Galley Head there were four, thus involving double the consumption of the illuminating material, whether oil or gas. Reference had been made by Mr. Wigham to a patent granted to him on the 5th of April, 1872, No. 1015, Mr. Douglass. "Improvements in illuminating lighthouses, beacons, harbour-lights, and light-ships." This patent was not, however, for the invention of superposed lenses, which had been in use for many years previous to that date; but it was for a special arrangement of two or more gas-burners, one burner above the other, together with their chimneys and flues, so as to form a source of light for dioptric lighthouses or beacon apparatus. No drawing or description of either a lens, oil-burner, or the necessary ventilating flue for the latter was to be found in the patent referred to. Mr. Wigham had stated the intensity of the flame of his 108-jet gas-burner, as measured by the late Mr. William Valentin in the presence of Sir James Douglass at Haisboro, in 1874, as 2,923 candles. Mr. Wigham had, however, omitted to state the actual dimensions of this flame as measured at the time by Mr. Valentin and Sir James Douglass. These dimensions and a diagram of the flame were given in the Paper of Sir James Douglass, on "The Electric Light applied to Lighthouse illumination."[1] It would there be seen that the flame of the Wigham 108-jet gas-burner had an area at the vertical section, or focal area, of 182 square inches. The initial intensity per square inch in the focal area was thus 2,923 ÷ 182 = 16·1 candles. The dimensions and a diagram of the flame of the four-wick oil-burner designed by Fresnel for application in his optical apparatus of the 1st order dimensions, had also been given by Sir James Douglass with those of the Wigham burner. The intensity of the flame of the Fresnel burner would be found to be 269 candles, and the focal area 10·5 square inches; the initial intensity per square inch in the focal area was thus 269 ÷ 10·5 = 25·6 candles, being 59 per cent. superior to the Wigham flame in this important requirement of a lighthouse luminary. Further, with regard to focal compactness, it would be observed that the superior efficiency of the flame of the old four-wick Fresnel burner, in the focus of a dioptric apparatus of the 1st order of his system for producing flashing lights, when compared with the flame of the 108-jet gas-flame of Mr. Wigham, was as 182 ÷ 10·5, or as 17 to 1 nearly.

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[1] Minutes of Proceedings Inst. C.E., vol. lvii., p. 108, and Plate 7.

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4 December, 1883.

JAMES BRUNLEES, F.R.S.E., President,
in the Chair.

The following Associate Members have been transferred to the class of

Members.

George Chatterton, M.A.
Samuel Fitzhugh Cox.
John Craig, B.A.
Waynman Dixon.
Philip Rickman Emmott.
John Edward Hilton.
William Langdon.
Frank Livesey.
Playford Reynolds.
James Rice.
William Blomefield Tripp.
Robert Edward Wilson.

The following Candidates have been admitted as

Students.

Richard Alexander Arnold.
Edwin Baggs.
Henry Cuthbert Barnard.
Charles Joseph Batley.
John Ernest Bloomfield.
John Blair Buchanan.
Frederick Septimus Berkeley Calcott.
Robert Alfred Carr.
Charles Percy Elliott Cheffins.
John Folliott Mostyn Clarke.
Francis Edward Cockshott.
Harry Vaughan Cowley.
Charles Richard Crook.
Edward John Mines Davies, Wh. Sc.
Augustine Campbell Davison.
Gilbert Francis Eliott.
George Randell Evans.
George Beckett Homer Fenton.
Maurice Fitz-Maurice.
Hugh Stowell Gell.
Pedro Juan Gomez.
Reginald William Griffiths.
Edmund Lyons Wellesley Haskett-Smith.
Alfred John Hill.
George Robertson Hooper.
William Hurst.
Francis Valentine Johnson.
James Johnston.
John Jones.
William Henry Jones.
Patrick John Joseph Kirwan.
Alfred William Long-Parkhouse.
James Charles McGeorge.
James Gilbert Stevenson Macintyre.
Charles Henry Mathew.
Harry Allaster Orpen Moriarty.
Edward Leslie Robert Muir.
Yeiji Nakashima.
Archibald Scott Napier.
Herbert Smales Newmarch.
Thomas Benson Nowell.
Oscar Oertel.
Frank Overton.
Gompei Oya.

Students—continued.

Alfred Cecil Pereira.
Basil Edwin Philips.
George William Porteous.
James Prentice.
Herbert Tatham Procter.
John Pryde.
Alfred Finch Randall.
Frederick Leitching Rubidge.
Frederick Robert Ryman.
Charles Thornton Rennie Scovell.
Guy Seaton.
David Simson.
Robert Skelton.
John Grice Statter.
John Charles Stewart.
John Percy Stuart.
Henry Lear Tarbet.
Henry Tomlison, Jun.
Charles Robert Trewhella.
Montgomery Waddell.
Robert Warrack.
John Edward Watson.
Morgan John Manderstjerna Williams.
Alan Wilson.
William Worsfold.

The following Candidates were balloted for and duly elected as

Members.

James Arthur Anderson.
Rowland Childe.
William Whitney Dartnall.
Robert Denny.
Charles Blackburn Dunlop.
Thomas Richard Guppy.
Peter Sharp Hyslop.
William Francis Jackson.
Henry Christopher Mance, C.I.E.
Camillo Maria de Menezes.
George Henry Phipps, Jun.
Professor Osborne Reynolds, M.A., F.R.S.
Madhubchunder Roy, B.A., B.C.E.
David McNeely Stauffer.
Charles Tylden-Wright.

Associate Members.

Edward William Anderson, Stud. Inst. C.E.
George Gray Anderson.
Lala Balmokand.
Charles Henry Barratt, Stud. Inst. C.E.
Propicio Pedroso Barreto.
Willoughby Bazalgette, B.A.
William Lee Beardmore, Stud. Inst. C.E.
Robert Berridge.
Charles Frederick von Bibra.
William Bramham.
Arthur Cardwell Brown.
Frederick Benjamin Brown, Stud. Inst. C.E.
Charles Ziethen Bunning, Stud. Inst. C.E.
Harvey Caldicott, Stud. Inst. C.E.
Robert Lewis Campbell.
Edward Richard Carolin.
Henry William Clarke.
Thomas Alfred Colfox, Stud. Inst. C.E.
Hubert Congreve, A.K.C., Stud. Inst. C.E.
Benjamin Crosland.
William Elmitt Curry, Stud. Inst. C.E.
Frederick Arthur Darlington.
Robert Dougal.
Thomas Duncan.
Francis Joseph Ede, Stud. Inst. C.E.
Sydney Firth, Stud. Inst. C.E.
Lala Ganga Ram.
James Gaskell.
Albert Augustus Gill.
Robert Campbell Grant.
Arthur William Herbert, Stud. Inst. C.E.

Associate Members—continued.

Charles Henry Howorth.
Ashley John Hunter.
Thomas William Keele.
Malcolm Æneas MacBean.
Leslie Duncan Macgeorge.
Francis William MacLean, Stud. Inst. C.E.
Wellwood Maxwell, Stud. Inst. C.E.
George Barker Mercer, Stud. Inst. C.E.
Robert Sydney Milles, Stud. Inst. C.E.
Richard St. George Moore, Stud. Inst. C.E.
Robert Edward Nelson.
Hugh Nettlefold, Stud. Inst. C.E.
Matthew James Joseph Patrick Norman.
Charles Edward Peake.
Richard Syer Robinson, Stud. Inst. C.E.
Raymond Hamilton Roope.
Alexander McDonald Salmon.
Thomas James Scoones.
Frank Walter Scott.
Walter Edward Slade, Stud. Inst. C.E.
William Joseph Howard Smith.
John Edward Stafford.
William Stubbs.
Joseph Swarbrick.
Philip Alexander Thomas.
John Thornhill.
Domingos Guilherme Braga Torres.
Robert Louthian Trevithick.
John Trump, Stud. Inst. C.E.
Edmund Henry Tuck.
Richard Waddington, Stud. Inst. C.E.
Henry Titus Wakelam.
Francis Samuel Wilde, Stud. Inst. C.E.
Lewis Thompson Wright.

Associates.

Arthur Stanhope Aldrich.
Professor William Boyd Dawkins, M.A., F.R.S.
William Lorimer.
Joseph Randall.
Lieut.-Colonel Percy Smith, R.E.
Richard Everard Webster, Q.C.

(*Paper No. 1956.*)

"On Electrical Conductors."

By William Henry Preece, F.R.S., M. Inst. C.E.

In no branch of engineering has the mutual dependence and reaction between practice and theory been more beneficial than in the useful appliances of electricity. Without theory the rule-of-thumb telegraphist would have been stationary. Without practice the electrician would have been a dreamer. The practical difficulties of telegraphy incited the physicist to trace out the laws that govern the behaviour of this subtle Power of Nature, and the appearance of new facts has driven the practical telegraphist into lines of inquiry and discovery. Physicists have been metamorphosed into practical engineers, while no telegraph-engineer deserves that title unless he also possesses that of a scientific man.

These conclusions are very strongly illustrated by the improvements made in the quality of the conductors employed for the transmission of electric currents.

Copper.—In the first telegraphs of 1837 nothing but copper wire, owing to its high position as a conductor, was used in England, and it was buried underground; but the difficulty then experienced in insulating buried wires was so great, that they were removed from underground and suspended on poles.[1] The ductility, the want of tensile strength, and the absence of elasticity of copper, as then produced, rendered it impracticable for this purpose. It was speedily replaced by iron. Iron has since been almost universally used for aerial lines, while copper remains the sole material for underground and submarine purposes where mechanical strength is of little consequence. Mechanical strength and price seem to have been the only considerations that governed the choice of conductors in the earlier days; but as soon as speed of transmission assumed a commercial aspect, as it did in 1858, when Atlantic telegraphy was an accomplished fact, then the electrical qualities of the material engaged the attention of the telegraph engineer. Sir William Thomson in 1856 pointed out the great differences in conductivity observable in various samples submitted to him, although these samples were supposed to be of the very best quality; while the late Mr. Augustus Matthiessen in 1860 made an exhaustive inquiry into these variations and their causes. He determined the electrical conductivity of pure copper, and defined a standard which is that now in use,[2] and showed that the variations were due to impurities, principally oxygen and metalloids. A mere trace of arsenic reduced the conductivity 40 per cent., while contact with air when in a molten state reduced it 24 per cent.

The result of Matthiessen's inquiries has been not only to remove the great variations in the conductivity of the copper, but to immensely improve its quality. While in 1861 electricians were content to specify that the copper should not fall below 85 per cent. of pure copper, they now specify 96 per cent., and they obtain it of a remarkably uniform quality. The value of this improvement may be estimated from the fact, that the carrying capacity of a cable for messages is increased in the same pro-

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[1] In 1848 a copper wire was put up between Paris and Rouen.

[2] Matthiessen's standard is 100 inches, weighing 100 grains, giving 0·1516 ohm at 60° Fahrenheit.

portion as the conductivity of the copper is improved. Thus a cable made of the copper of to-day will carry twice the number of messages that a similar cable of copper would in 1858.

The progressive improvement is shown by the following Table:

Cable.	Year.	Conductivity.
Dover and Calais	1851	42·00
Portpatrick and Donaghadee. .	1852	46·00
Atlantic Cable	1856	50·00
Red Sea	1857	75·00
Malta and Alexandria . . .	1861	87·00
Persian Gulf	1863	89·14
Atlantic cables	1865	96·00
Irish cable	1883	97·90
Pure copper	..	100·00

It is not, however, alone in cables that an improvement of working has been effected by increasing the conductivity of the copper. It has imported additional efficiency to the apparatus. Greater useful effects are obtained with the same current. In all the practical applications of the current, it has an economical advantage, for it lessens the waste of energy in the circuit in direct proportion to the improvement effected. In an electric-light main a difference of 10 per cent. in the purity of the copper might lead to the waste of several HP. The test for purity is extremely simple. Every text-book, or book of tables, has the resistance of a foot-grain, a metre-gram, a mile-pound, or a knot-pound,[1] of pure copper at every degree of ordinary temperatures—call this R_t. Take a piece of the cylindrical conductor to be measured. Let w be its weight, l its length, then

$$\frac{R_t\,l^2}{w} = r_1$$

gives its resistance at the temperature at the point of observation if it be truly cylindrical and the copper be pure; but by actual measurement it will be found to be r_2. Then

$$\frac{r_2}{r_1} = \frac{100}{x}, \text{ or } x = 100 \times \frac{r_1}{r_2}.$$

and x is its percentage of purity.

The resistance of all metals is very much affected by temperature. Matthiessen studied this with great care. He found that

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[1] 1 metre weighing 1 gram = 0·144 ohm at 0° C.
1 foot ,, 1 grain = 0·2064 ,, ,,
1 knot ,, 1 pound = 1091·22 ,, ,,
1 mile ,, ,, = 842 ,, ,,

within ordinary limits the increase due to higher temperatures was approximately expressed by the formula.

$$R_t = R_o (1 + a\,t),$$

where R_0 is the resistance at 0° C., and R_t the resistance at the temperature t. He ascertained the coefficient a to be for pure copper 0·0038. Thus the resistance is increased 38 per cent. between the freezing and boiling points, and it may therefore be increased 20 per cent. between winter and summer temperatures. Hence it is desirable to determine the efficiency of electric-light leads at the highest temperature to which they will be exposed, to avoid unnecessary and injurious waste of energy.

But copper is not only used for submarine cables and for underground lines; it is also employed for overhead wires through towns and many smoky districts. It is not so readily attacked by the gases in the air as is iron or zinc. For such purposes, however, mechanical strength, which is of little consequence in insulated wires, becomes of essential importance.

Copper wire when in the process of manufacture is always drawn cold, and is said to be "hard-drawn" before it is subjected to the annealing process, after which it is called "soft." Soft copper always gives a higher conductivity than hard-drawn copper, but its tensile strength is reduced. Pure soft copper has a very small breaking strain, probably under 10 tons on the square inch, but hard-drawn copper is now supplied that has a breaking strain of 28 tons on the square inch.

Copper wire has been erected in localities where iron wire is destroyed in a few months, and now, after four years' experience, it appears practically unaltered. The diameter of the wire has not been lessened $\frac{1}{1000}$ inch, and it maintains its original qualities unimpaired. In the neighbourhood of chemical, varnish, and other works it becomes encrusted with a thick deposit, but beneath this it remains unaffected.

Age alone, as far as experience extends, seems to have no appreciable influence on the quality of unstrained copper. Its conductivity and its ductility remain constant. But when copper wire has been removed from magnet coils, such as the field magnets of a dynamo, it becomes brittle, but curiously enough this seems to occur even when the magnets are out of use. Mr. Sabine has found that silk-covered wire, particularly of the finer sizes, wound upon experimental apparatus, gets in a few years equally brittle, whether the instrument is thrown aside or whether it is continuously at work. Neither paraffin nor electro-gilding check this brittleness. It is probably an effect due to the strains that the wire experiences when wound on a reel and subject to the incessant variations due to change of temperature.

Matthiessen observed no difference produced by the passage of electric currents. The conductors of the Atlantic cables laid in 1858, 1865, and 1866 are found as perfect now as when they were made. The conductors of all cables seem to remain constant. But Gaston Planté[1] discovered that the continued discharge of great quantities of electricity through fine wires rendered them brittle, and Callaud asserted that lightning conductors were very brittle. If that be so, some result may be anticipated from the employment of currents for electric lighting. At present there has scarcely been sufficient experience to teach much on this point.

It is well known that impure copper and its alloys, particularly brass, become brittle when exposed to atmospheric influences in workshops, but this influence has not been observed in telegraphic conductors.

Wires more than twenty years old, used as battery leads, and constantly subject to the transference of electricity through them, show no signs of deterioration. The experience of telegraph engineers is entirely in favour of the constancy and durability of copper as a conductor.

The size of conductors is governed by strictly theoretical conditions, dependent upon the purposes to which they are applied, and it is controlled by commercial considerations. In telegraphy speed of working is the criterion; in electric lighting, and in the transmission of power, waste of energy is the criterion. Sir William Thomson has given a law which indicates that the annual value of the wasted energy must equal the interest on the capital expended in laying down the conductor to give the maximum useful economical result. Any departure from this law, to secure lower capital expenditure, means shortsighted policy and non-scientific practice.

Copper is imported into the country either as ore or as regulus, bar or ingot. The purest comes either from Japan, Chili, Australia, or from Lake Superior. Much pure copper is produced by the Swansea method of copper-smelting, especially by the modification of that system known as "best selecting;" but within the last few years very pure copper for electrical purposes has been obtained by improvements in the treatment of the metal in the smelting and refining furnaces, some of which have been so successful that

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[1] "Comptes Rendus de l'Académie des Sciences," vol. lxxxix., 1879.

there is no difficulty in getting metal giving an electrical conductivity equal to 99 per cent. of pure copper. Great purity of copper is also arrived at by electro-deposition, of which there are two methods—the one by depositing the metal from a solution obtained from the ore, the other by using impure copper as the anode in a depositing bath containing a standard solution. Electro-deposited copper has not the same mechanical strength as ordinarily refined copper.

At the Paris Electrical Exhibition of 1881 there was one coil of copper wire 1·3 millimetre in diameter, weighing 181 kilograms, and measuring 15 kilometres long.

Iron.—Iron has been hitherto used exclusively for overhead wires. In the first days of gutta-percha, about 1849, iron was employed as the conductor to be coated with the new gum, but its inapplicability for this purpose was speedily discovered. Its abundance, its cheapness, and its admirable mechanical properties have singled it out for practical telegraphic purposes; but its resistance is very high, and materially increases the difficulties of the telegraphic engineer. The great improvements effected in the electrical qualities of copper, directed attention to the same qualities in iron; but although copper has been so vastly improved, the same progress has not been made with iron. Copper refiners have relied more upon the aid of the chemist than iron-wire manufacturers. In fact the improvements made have been forced upon the latter. The process in this case has been more tentative and less scientific. There is still room for progress. Although the Author had for many years advocated attention to this point, the Americans were the first to specify conductivity in applying for tenders. They defined a standard which was called the Ohm-mile—that is, it was the weight of a cylindrical wire 1 mile in length, which gave a resistance of one ohm at 60° Fahrenheit. While the first iron wire supplied under this specification gave a mile-ohm[1] of 5,500 lbs., it is now frequently obtained as low as 4,520 lbs. In the present specification of the Post Office the fixed maximum resistance is equivalent to a mile-ohm of 4,800 lbs.

The amelioration made in the quality of iron wire is illustrated by the following measurements:—

	Inch.	Ohms.
1873 Iron wire . . .	0·171	15·31 per mile.
1883 „ „ . . .	„	11·30 „ „

In the earlier days of the telegraph best puddled-iron was used

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[1] Mile-ohm is more euphonious than ohm-mile, and is used in preference.—W. H. P.

for wire, which, however, was very liable to splits and flaws, and an alteration was made by using piled puddled-iron or B B (best-best). This description was again improved by the introduction of "box-piled iron" of puddled and English charcoal, sometimes called extra B B, and by four-sided charcoal-piled iron of English charcoal and puddled, which has been called extra special BB; but the terms B B, &c., have now lost all significance—the commonest description of fencing wire only being known by the term. During the last decade a mild English Bessemer steel has been very largely employed, especially for railway-telegraphs, and for staying purposes; but the resistance of most wires of this description is high, averaging about 6,800 lbs. per mile-ohm, this high resistance being mainly due to the high percentage of manganese, which in this description of wire varies from 0·25 to 0·75 per cent. The wire used by the Post Office is of Swedish charcoal-iron, with a mile-ohm resistance, as already stated, of about 4,520 lbs. Swedish Bessemer, or a specially prepared low-carbon English Bessemer, is used by the Indian government, with a mile-ohm resistance of about 5,400. Cast-steel wire, with a breaking-weight of about 80 tons to the square inch, has been adopted on the Continent for telephone circuits with a mile-ohm resistance of 8,000 lbs. The Table (p. 70) will show at a glance the various descriptions of iron and of steel telegraph wire which are now in use, or have been used, the tests being given for 0·171 inch, or 400 lbs. to the mile, that being the standard size in England, and a size very largely employed throughout the world.

It will be noticed by Table A, that while in England, where speed of working is the prime consideration, and length of span may be neglected, electricians are satisfied with a breaking-strain of 22 tons on the square inch; in the Colonies, where long spans are essential, and speed of working is not so important, the specification is 30 tons on the square inch.

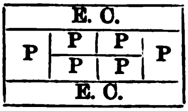
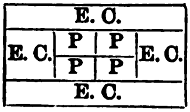
The chemical analysis of samples of different wires, with their approximate resistances when annealed for use as telegraph-wire, Table B, will be interesting:—

ANALYSIS of SAMPLES of DIFFERENT WIRE.

No. 1. Swedish Charcoal Iron, very soft and pure.
„ 2. Swedish Charcoal Iron, good for P. O. specification.
„ 3. Swedish Charcoal Iron, not suited for P. O. specification.
„ 4. Swedish Siemens-Martin Steel, 0·10 carbon.
„ 5. Best Puddled Iron.
„ 6. Bessemer Steel, special soft quality, 0·15 carbon.
„ 7. Bessemer Steel, special hard quality, 0·45 carbon.
„ 8. Best Cast Steel.

TABLE A.—MECHANICAL and ELECTRICAL TESTS of SEVEN DESCRIPTIONS of IRON TELEGRAPH WIRE.

Four samples of each kind.

Description.	Diameter.	Twists in 6 inches.	Elongation.	Breaking Weight.	Resistance per Mile reduced to 0·171 inch at 60° Fahr.
			Per cent.	lbs.	
1. "B B" puddled iron . .	174½	16	17½	1,470	14·4200
	176½	13	11½	1,380	13·5592
	165	14	15½	1,436	13·8897
	173½	17½	14	1,182	13·8983
2. "B B" piled iron, all puddled	171	16	17	1,220	14·0582
	164½	9	13	1,316	15·5820
	164½	12	11½	1,238	15·6234
	172½	17½	16½	1,292	14·1640
3. "Extra B B." Box piled of puddled and English charcoal, thus—  [1]	168	11	14½	1,456	15·6191
	174	10½	15	1,538	15·3715
	169½	11½	16	1,398	15·5452
	172	12	14½	1,452	15·3017
4. "Extra special B B." Four-sided charcoal-piled English charcoal, and puddled thus—  [1]	172	15	15	1,420	15·5129
	168½	14	14½	1,412	15·6844
	172	10½	14	1,484	16·3574
	172	15	16	1,478	15·5471
5. English Bessemer (known as homogeneous iron) .	171½	20	16	1,634	15·9988
	169	19	13½	2,118	18·5663
	170	19½	17½	1,484	14·6922
	168¾	12	14	2,548	19·1480
6. Swedish Bessemer . . .	173½	21	17	1,392	12·6808
	174½	20½	12	1,380	12·9709
	173½	22	18	1,456	13·6587
	171½	13½	17½	1,318	13·0222
7. Swedish charcoal . . .	171	23	13½	1,191	11·3490
	169½	25	10	1,358	11·3052
	169½	24½	13½	1,194	11·2241
	171¼	27½	13	1,128	11·3133

[1] E. C. = English charcoal. P = puddled iron.

TABLE B.

No. of Samples.	1	2	3	4	5	6	7	8
Carbon . .	0·090	0·100	0·150	0·100	0·100	0·150	0·440	0·620
Silicon . .	trace	trace	0·018	trace	0·090	0·018	0·028	0·060
Sulphur .	trace	0·022	0·019	0·035	0·030	0·092	0·126	0·074
Phosphorus.	0·012	0·045	0·058	0·034	0·218	0·077	0·103	0·051
Manganese.	0·060	0·030	0·234	0·324	0·234	0·720	1·296	1·584
Copper . .	trace	trace	trace	trace	0·015	trace	trace	trace
Iron . .	99·690	99·700	99·440	99·600	99·110	98·740	98·200	97·410
Mile-ohm at 60° Fahr.	lbs. 4,546	lbs. 4,502	lbs. 4,820	lbs. 5,308	lbs. 5,974	lbs. 6,163	lbs. 7,468	lbs. 8,033

This Table shows in a very striking way that the electrical conductivity of iron wire increases with the percentage of pure iron, except where the percentage of manganese is high; an increase in the percentage of manganese augments the electrical resistance considerably more than an increase in the percentage of sulphur or phosphorus.

The durability of iron wire is maintained by galvanizing—a most inappropriate title for a very simple operation. The wire, which is first chemically cleaned by being passed through a bath of hydrochloric acid, is then drawn through a bath of molten zinc, at such a pace as will secure the adhesion of the requisite layer of zinc. The zinc becomes oxidised when exposed to the air, and since zinc-oxide is insoluble in water, the wire is protected with an impervious coating; but when this zinc-oxide is exposed to sulphur-acids it becomes converted into zinc-sulphate, which is soluble. Hence the zinc is removed, the iron is exposed, and oxidation and destruction rapidly supervene.

When the galvanized wire is to be suspended in smoky districts, it is additionally protected by a braided covering, well tarred. In some countries galvanizing is not resorted to, but simple oiling with boiled linseed oil is depended upon. Such a wire was erected in 1856 between London and Rugby, but the result was very unsatisfactory. More recently (1881) the experiment has been repeated with a similar result. In this climate galvanization is imperative.

But it is not alone in smoky districts where iron wire decays. It suffers much along the seashore. The salt spray decomposes the zinc-oxide into soluble compounds, which are washed away and leave the iron exposed, and this is speedily reduced to mere thin red lines.

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[1] "The Electrician." October 16, 1880, p. 253.

Where external decay is not evident, time seems to have no apparent effect on iron wire. Wire that has been erected for forty years seems as strong, as elastic, and as conductive as it was at first. In pure country air its durability seems infinite; but sometimes, especially through fir forests, it is subject to some corroding influence. Bauschinger in 1878 tested iron taken from chain bridges that had been erected in 1827 and in 1852, and found the strength and elasticity unimpaired. Thurston found the same in Philadelphia after forty years' exposure. Thirty-nine years of incessant service in conveying currents for telegraphy have not apparently altered the molecular structure of iron wires in the open country on the London and South Western Railway.[1]

Manufacture.—Swedish charcoal-iron being now the only description used by the British Post Office, the Author has selected it for describing the manufacture of iron telegraph-wire. It is imported either in bloom or in rods, principally in rods. Each rod is rolled down to about 0·26 inch in diameter, and weighs on the average about 1 cwt.

Iron wires used to be drawn in very short lengths, weighing from 15 to 20 lbs. involving numerous welds, splices, or joints—points of great weakness—but now they can be rolled and drawn into lengths longer than are practically required. Coils 0·171 inch in diameter, weighing 400 lbs. and measuring 1 mile have been exhibited, but 110 lbs. is about the best practical limit for transport and use.

By the mills invented by Mr. George Bedson, of Richard Johnson and Nephews, Manchester, the billets can be rolled in this country without welds into rods weighing upwards of 1 ton in weight; and the Author would mention how much telegraph engineers are indebted for the modern improvements in telegraph wire to the various inventions of this gentleman.

The Swedish iron owes its value not only to its comparative purity, but to the fact that it is smelted and puddled entirely with charcoal. The best qualities are a mixture of various ores, and they are known by various brands, the conditions determining these brands being secrets.

The rods arrive in this country dirty and rusty, and the first operation is to cleanse them. This is done by immersion in a bath of diluted sulphuric acid which thoroughly removes every trace of oxide and dirt. The clean rods are then coated with

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[1] Journal of the Society of Telegraph Engineers, 1880, vol. ix., p. 44. "On the Durability of some Iron Wire," by William Henry Preece.

lime to prevent further oxidation, and well baked to dry off all trace of acid. One end of each rod is next pointed to admit of insertion in the draw-hole, and it is then drawn down by one operation to No. 5 W.G., or 0·212 inch in diameter. The act of drawing the wire considerably modifies its molecular structure. It becomes "short," and before it can be drawn down to a smaller size, it must be well and carefully annealed. It is then again cleaned and coated with lime, and reduced to 0·171 inch in diameter. Since the drawing down has again shortened the texture, it has once more to be annealed, before receiving its final operation of galvanization. After galvanization it is straightened by being drawn through a series of jockey rollers, and wound round two wheels, one of which has a slightly quicker motion than the other. It is finally gauged and tested before being stored away for future use.

The Author has described the manufacture of 400-lbs. wire, which is that principally adopted for telegraphic purposes in England, but the explanation is equally applicable to any other size—the wire after each drawing being annealed.

Testing.—The operation of testing is a most important one, and requisite not only for the user, but also for the manufacturer. Flaws, impurities, faults, notwithstanding the greatest care, will occur, and they can be detected only by the most rigid examination and tests. Tests are mechanical and electrical. The mechanical tests embrace one for breaking-strain, another for elongation, and a third for torsive capacity. For hard steel-wire, in place of the torsion test, it is usual to specify that the wire shall bear wrapping round its own diameter and unwrapping again without breaking. In France the torsion test is replaced by another by which the wire is bent at a right angle backwards and forwards four times for wire 4 mm. in diameter. Special machines are constructed for the mechanical tests, the condition to be fulfilled being that for the breaking-strain the increasing load or stress shall be applied uniformly, without jerks or jumps, and the elongation-machine shall correctly register the actual stretch without the wire slipping. The torsive capacity of the wire is determined by an ink mark which forms a spiral on the wire during torsion, the number of spirals indicating the number of twists taken before breaking. The electrical test is simply that for resistance—$\frac{1}{30}$ of a mile of the wire to be examined is wound round a dry wooden drum; and its electrical resistance is taken in ohms by means of a Wheatstone's bridge. Galvanization is tested by dipping in sulphate of copper, and by bending or rolling round a bar of varying diameter, according to the size of the wire.

Specification.—The perfection to which the manufacture of iron wire has been brought is greatly due to the care bestowed upon the specifications by the authorities of the Post Office and of the India Office. No lesson of experience has been neglected; no point has been left open to doubt. The standard has been gradually raised, until it is now very high. It is fixed, and not subject to those continual changes that are irritating and expensive to the manufacturers, who have in consequence been able to select their materials, and to ascertain by experiment the best methods of treatment to produce the high results required.

It cannot be too strongly urged that specification without rigid inspection is valueless. The manufacturer who for his own reputation, and in obedience to the dictates of his conscience, strictly complies with the requirements of a rigid specification at the expense of his pocket, without the check of a subsequent inspection, may exist in theory, but he is not found in practice. Equally difficult is it to find the careful and painstaking inspector who, possessing the requisite technical knowledge and experience, will rigidly perform his task, regardless of the blandishments of those whose interests are affected by his blindness or carelessness. Many administrations object to the expense of thorough inspection, and the result is they are the recipients of the rejected material of those who do rigidly inspect. One break in the wire costs far more than its inspection, and one extra ohm per mile affects the earning capacity of the wire in inverse proportion.

It is, however, necessary to remark that the mechanical quality of charcoal-iron wire sometimes changes with time—its electrical quality remaining unaffected. The molecules seem to set, and the wire to become harder. This is shown by a diminution in the number of twists, and by an increase in the tensile strength. Tests repeated at some subsequent period may therefore be deceptive, unless allowance be made for the effect of time. Bessemer or homogeneous iron wire as a rule improves in its mechanical properties by being kept in stock.

Gauge.—The vexed question of gauge as applied to wire has been fought with well-nigh the same energy as that of railway gauges. The result is, that confusion has become more confounded. The various Birmingham wire-gauges—as various as the seats of the manufacture of iron—were consolidated into one very useful gauge by the Society of Telegraph Engineers; but the Board of Trade has recently taken up the subject, and has issued another gauge, which has the merit of being authorised. It is fixed and legal, and therefore it must be accepted. However, it departs so seriously from all recognised gauges, and ignores so completely the metrical system, which is steadily and surely making its way into commercial use, that the Post Office authorities have decided to abandon a gauge altogether as applied to conductors, and to define size by diameter and weight. Thus, in future, all copper wires will be known by their diameters in "mils," or thousandths of an inch, and all iron wires by their weights in lbs. per mile. The following Table gives the iron wires generally in use:—

Weight per Mile.	Diameter.	
lbs.	Inch.	Millimetres.
800	0·242	6·0
600	0·209	5·2
400	0·171	4·3
200	0·121	3·0
60	0·066	1·85

Steel wire is used for long spans, or for places where great tensile strength is needed; but it is for the external strengthening of deep-sea cables that steel wire is principally adopted. It was first employed in the Atlantic cable of 1865 for this purpose. It has since been generally used for deep-sea cables. The usual diameter is 0·099 in., and it is specified to bear a breaking-strain of 1,400 lbs., which is equivalent to 81 tons on the square inch. Steel wire has been produced giving a much higher tensile strength.

Compound Wire.—A compound wire of steel and copper was introduced in America about 1874. It had a steel core for strength, with an envelope of copper to secure conductivity and durability. It has a weight only one-third of an iron wire of the same resistance. It has been extensively tried in both hemispheres, but without success. It has been impossible to secure permanent adhesion of the envelope and its core. Moisture has in course of time entered, the steel has corroded away, and this even though the copper envelope has been deposited electrolytically. Light wires of great strength and of low resistance would be of inestimable value to the telegraph engineer, and the failure of the compound wire has been a source of much regret.

Recently a compound wire has been erected between New York and Chicago, a distance of 1,000 miles, giving only 1·7 ohm-resistance per mile. It has a steel core 0·125 inch in diameter, and is coated with copper electrolytically to a diameter of 0·25 inch. It weighs 700 lbs. per mile. It is very expensive. Hard-drawn copper, or silicium-bronze of a much lighter character, would be equally efficient, at probably one-half the cost.

Bronze Wire.—Phosphor-bronze, the hard mechanical qualities and great resisting powers of which are well known, was introduced for telegraph wire about five years ago. Several lengths were erected by the Post Office. Two long spans cross the channel that separates the Mumbles Lighthouse from the headland near Swansea. The object in view was to obtain great tensile strength, with a power to resist oxidation, especially active where the wire is exposed to sea-spray. This was done in 1879, and now, in November 1883, not the slightest change is noticeable in the wire. But phosphor-bronze, though extensively used, has high electrical resistance; its conductivity is only 20 per cent. that of copper. Moreover, the phosphor-bronze originally supplied was irregular in dimensions and brittle in character. It would not bear bends or kinks. Great improvements have recently been introduced to remedy these disadvantages.

Phosphor- and silicium-bronze derive their names, not so much because phosphorus and silicium are mixed with the copper, but because they are used in the preparation of the alloy. Pure bronze is a mixture of copper and tin, and in the refining and mixing process phosphorus and silicium have the property of removing impurities, particularly the oxides, though doubtless some of the flux remains. Phosphorus has a most injurious influence on the electrical resistance of the alloy. Silicium is far superior; hence the silicium-bronze is preferable for telegraphic purposes. Its efficiency is very great; in fact, phosphor-bronze has disappeared for telegraph wire, and has been replaced by silicium-bronze.

The conductivity of silicium-bronze can be made nearly equal to that of copper, but its mechanical strength is diminished as its conductivity is increased. Wire whose conductivity equals 90 per cent. of pure copper, gives a tensile strength of 28 tons on the square inch; but when its conductivity is 34 per cent. of pure copper, its strength is 50 tons on the square inch. Its lightness, combined with its mechanical strength, its high conductivity and its indestructibility, render it eminently adapted for telegraphs.

The Table below gives the results of some tests made by the Post Office upon different specimens of bronze and copper submitted for trial.

Long telegraphic lines, for which iron wire weighing 400 lbs. per mile is now used, can be made of copper or of bronze wire weighing 100 lbs. per mile, which would give higher electrical efficiency; and over-house lines, for which steel wire is often used, can now be replaced efficiently by wire weighing only 30 lbs. per mile, which would be almost invisible.

EXPERIMENTS on DIFFERENT QUALITIES of WIRE.

Diameter.		Weight per Mile in Pounds.	Elongation Per Cent.	Breaking Weight in Tons per Square Inch.	Twists in 6 inches.	Resistance in Ohms at 60° F.		Conductivity. Copper =100.
Inch.	Mm.					Per Mile.	Per Foot-Grain.	
Silicium-Bronze—								
·080	2·056	102·650	1·5 : 1·0 2·0 : 2·0	27·610	13 : 16 23 : 35	8·6359	0·22258	94·616
·059	1·529	58·651	nil nil	29·368	21 : 25 27 : 53	15·4370	0·22734	92·637
·044	1·133	32·310	nil nil	47·406	24 : 25 24 : 26	90·3330	0·73285	22·826
·036	0·936	22·698	nil nil	50·070	23 : 19 11 : 22	157·3900	1·43750	14·650
·081	2·072	102·170	1·5 : 1·0 1·5 : 1·0	29·022 27·470	47 : 19 16 : 20	8·5009	0·21807	96·571
Copper—								
·081	2·072	106·100	nil nil	30·322	16	11·3490	0·30235	69·60
·082	2·088	107·630	1·5 : 2·5	29·164	27	9·4400	0·25538	82·50
·0847	2·136	116·400	0·5 : 1	30·306	50	9·2400	0·26995	78·00
·081	2·072	105·310	0·5	28·416	84	8·4100	0·22245	94·60

If such overhead-wires were erected upon sightly supports, and with some method, there would be an end to the meaningless crusade that is now made in some quarters against aerial lines. These, if constructed judiciously, and under proper control, are far more efficient than underground lines. Corporations and local authorities should control the erection, rather than force administrations to needless expense and to reduced efficiency by putting them underground. Not only do light wires hold less snow and less wind, but they produce less electrical disturbance;

they can be rendered noiseless, and they allow existing supports to carry a much greater number of wires. Other bronzes have been tried, but without any evident advantage, either in quality or in price.

German Silver.—German silver is employed generally for rheostats, resistance coils, and other parts of apparatus in which high resistance is required. It consists of:—

Copper	4 parts.
Nickel	2 „
Zinc	1 part.

The variation in its resistance due to changes of temperature is small. Its coefficient is 0·0004—copper being 0·0038—that is, about ten times less. Its resistance per metre-gramme is 1·85 ohm, while copper is 0·144 ohm. The effect of age on German-silver is very marked. It becomes brittle. Mr. Willeughby-Smith[1] has found a similar change with age, even in the case of wire drawn from an alloy of gold and silver.

Conclusion.—It is evident from what has been said, that the form and character of electrical conductors must vary with the purposes for which they are intended. For submarine cables and for electric-light mains, where mechanical strength is not required, and where dimensions are of the utmost consequence, the conductors must be constructed of the purest copper producible, for copper is the best practical material at command.

On the other hand, aerial lines must not only have great tensile strength, but in these days of high-speed apparatus they must have high conductivity, their dimensions must be such as to ensure low electrostatic capacity, they must expose to wind and snow the least possible surface, and they must be practically indestructible. Iron has hitherto occupied the field, but copper and alloys of copper seem in many instances destined to supplant that metal, and to fulfil all the conditions required in a more efficient way, and at no greater cost per mile.

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[1] Journal of the Society of Telegraph Engineers, vol. ix., p. 49.

[Discussion.

Discussion.

Mr. Brunlees.

Mr. **Brunlees**, President, said he thought the discussion might well be taken in three parts. First, as to the qualities which electrical conductors should possess; next, as to the manufacture of the conductors, and then, having the electric conductor according to the conditions laid down by men of science, and according to the possibilities of manufacture, on the practical use of the conductor. He would first ask Mr. Preece if he desired to add anything before the discussion commenced.

Mr. Preece.

Mr. **Preece** expressed his deep regret that one seat at the Council table was empty, a seat that had been filled by one who had taken a prominent part in the discussion of every electrical Paper brought before the Institution. The late Sir William Siemens had taken the deepest interest in the subject, and had succeeded very largely in enriching it. Mr. Preece had brought forward many facts to illustrate the improvement effected in electrical conductors during the last quarter of a century, and he hoped that the discussion would elicit other facts, showing how the mechanical and electrical qualities of the various metals had been almost metamorphosed. The chief point that he desired to emphasize was the position that copper was likely to take in the future, and the remarkable mechanical powers that it evinced. He had brought for inspection a number of specimens illustrating the behaviour of metals, and showing how they were produced. In speaking of them in his Paper, he had been compelled frequently to use a term which was familiar in the mouth of every electrician as a household word; but which had not yet become familiar to engineers—the term "resistance." He had spoken throughout the Paper of the resistance of wires, knowing well as an electrician, what the term resistance meant; but many engineers assumed that it meant mechanical resistance—resistance to tension or to rupture. It was a misfortune that the term had been too freely introduced, and it would have been better if he had spoken entirely in terms of conductivity. If he had said that a copper wire conducted electricity six times better than iron wire of the same dimensions, he should have been better understood than by saying that a piece of wire had one-sixth of the resistance, or six times the resistance, as the case might be. Sir William Thomson had pointed out in that room how it was that conductivity was the exact reverse or reciprocal of resistance, and he went so far as to suggest that there ought to be a standard for conductivity as

Mr. Preece. there was a standard for resistance. That point had not, however, yet been reached. But should he still use the term "resistance," he wished it to be clearly understood that he meant by it the reciprocal of conductivity. Resistance was expressed in terms of a standard called the ohm, and he believed the day was not far distant when every one would know what an ohm was as well as what a foot was, or what a metre was. The ohm-standard was expressed by certain length, a column of mercury, about 1 metre in length, of 1 square millimetre section. But in dealing with copper and with iron, a standard had been introduced expressed in weight per mile. Copper wire weighing 842 lbs. per mile, gave an ohm, and was called a mile-ohm of copper: iron wire weighing 4,500 lbs. gave a mile-ohm of iron; so that the relative dimensions of that curious standard depended both upon length and weight. He had brought for exhibition the various instruments that were used to test the metals, and he would show the test upon iron, and if time permitted, upon copper, for he wished the members to have distinct evidence of the remarkable mechanical qualities of the copper produced at the present day. The copper-wire specimens on the table possessed a breaking strain of 30 tons on the square inch, while the iron used for telegraphic purposes possessed a breaking strain of only 22 tons. Again, there was an impression that copper was very plastic, and that it stretched very considerably; but he had figures showing that it did not stretch so much as iron; indeed, the copper wire then used stretched considerably less than iron; so that in both properties, tensile-strength and elasticity, the copper of the present day was better than the iron. The machine exhibited was that used for testing the breaking-strain. There was a system of levers and a shifting weight. As at present arranged, the machine would register from 1 lb. to 5,000 lbs. There was a length of wire applied which was clamped in such a way that there was no nipping or biting, and it suffered no mechanical injury. When by means of the wheel and the multiplying gear a slow motion was brought to bear, a weight was gradually applied to the wire until it broke. The piece of wire tested weighed 400 lbs. to the mile, and it was known as 7½ by the centimetre gauge. (The wire was then tested for tensile strength.) The wire, it would be seen, had broken at 1,160 lbs., the specified breaking-strain being 1,080. It was also necessary to record the stretch, which was sometimes done at the same time; but it was better to do it independently. The second machine exhibited clamped a length of 10 inches. (The wire was here tested for stretch.) The wire, Mr. Preece.

it would be seen, had given way after stretching 15 to 16 per cent. Another test was the torsion test—a test for torsive capacity. It was not desired that the wire should resist torsion, but should bear torsion. By making an ink mark along the top, and by twisting the wire in the other machine until it broke, a series of spirals was formed, and the number of the spirals indicated the torsive capacity. All wires were specified to show a certain number of twists. The wire experimented upon was taken from a coil of No. 7½, and all the pieces had been cut off the same length. He would next experiment upon copper wire No. 14. Meanwhile, he would refer to the enormous advantage which copper wire would give for overhead purposes. There was then going on what he had characterised as a meaningless crusade against overhead wires. Vestries and other small corporations in outlying districts were endeavouring to force the Government to put the wires underground, and the newspapers were bringing forward the fact that even in Germany and France the wires were so placed. It was not sufficiently known that Germany and France were only doing what had been done in England a quarter of a century ago. The wires were then placed underground; all the main wires in the country between London, Birmingham, Liverpool, Manchester, Leeds, and all the wires to the cables on the South Coast, were underground; but after sufficient experience of their use it was found necessary to take them up again; and he should not be in the least degree surprised to find the same result taking place sooner or later in Germany and France. It had been found that wires overhead had many times the efficiency of wires underground, and it was absurd to try and force electricians to do an act that was commercially wrong and practically foolish for the imaginary reason that overhead wires were supposed to be dangerous. Statistics showed that in the United Kingdom there were 18,000 persons killed by accident every year. The average for the last thirty years—during the period of telegraphs—was about 12,000 per annum. In that period about 400,000 persons had been killed by accident, and of that number two only had been killed by telegraph wires. One of those accidents was owing to the foolish practice that he had lately seen suggested even in the *Times*, of having the wire tied to the railing of an area. If in that case the wire had been allowed to hang free, it could not have produced any injury. With the light, fine copper wires at present used it was scarcely possible to conceive that if they did break they could produce any harm. Why, then, should legislation be enacted for such a minimum of accident as was shown by the statistics to

Mr. Preece. which he had referred? He granted that the wires were very ugly, and no one going through Moorgate Street or Leadenhall Street could help being vexed to see the metropolis so much disfigured. That, however, was not because the wires were overhead, but simply because they were carried in a higgledy-piggledy, spider-web fashion, in any direction, without method or system. If the corporations wanted to do good it should not be by trying to force the authorities to place the wires needlessly underground, but by trying to exercise some control over those who erected wires overground. It had been thought, from the remarks he had made about the gauge, that he expressed disapproval of the gauge recently introduced by the Board of Trade; that, however, was not his object. The gauge was a very good one. It had been accepted by nearly everybody; it had been authorised, and it would do a certain amount of good. But what the Post Office objected to was that there should be so many changes. When it was found that a wire which had been known by their men as No. 8, was called at another time No. 7½, and at another No. 7¾, they decided, in order to avoid confusion, to abandon the gauge altogether, and simply to speak of the wire as of so much weight per mile. That method had been introduced into India with great success. He had stated that the great improvements in the manufacture of iron were due to the care bestowed upon the specifications of the authorities at the Post Office. He ought to add that the improvement was also due to the great care taken by the India authorities in improving the specification. (The copper wire was here tested.) It would be seen that the piece of wire experimented on had stretched 0·15 in 10·2 inches, or nearly 2 per cent. The other piece of wire was eighty-one thousandths of an inch in diameter, and it ought by specification to break at 320 lbs., which would be 27 tons on the square inch. It actually broke at 362 lbs., or 31 tons on a square inch.

Sir Frederick Abel. Sir Frederick Abel, C.B., Honorary Member, said that his remarks would be mainly with the view of eliciting further information, and, if possible, of adding a few supplementary facts with reference to certain points dealt with in the Paper. Reference had been made to the remarkably useful work done by the late Dr. Matthiessen, as far back as 1860, in regard to the influence exerted by different commercial impurities in copper upon its conductivity or electric resistance. The Author had correctly stated that those researches had not only greatly instructed them with reference to their knowledge of copper as an electric conductor, but had also led in a very important degree

Sir Frederick Abel.

to improvements in the treatment of copper, with special reference to the production of electrical conductors. It was stated in the Paper that Dr. Matthiessen had determined the electrical resistance of pure copper; but he was not quite sure whether in the present day—twenty-four years after the experiments—whatever reliance might be placed on the results obtained, the measurements given could be accepted as truly representing what the resistance of perfectly pure copper should be. Electricians had acquired a considerable amount of additional information, and they were on the way to acquire still more in regard to the influence of very minute proportions of impurities upon the electrical conductive powers and other physical properties of metals; and no one could teach them more in that direction than Professor Hughes, who had recently been pursuing some very remarkable researches. Therefore, although they still accepted with great confidence the results of Dr. Matthiessen, they might probably learn yet more with regard to the conductivity of really pure copper. In reference to the manufacture of copper wire, the Author had mentioned that soft copper always gave a higher conductivity than hard-drawn copper; its tensile strength being of course considerably lower. On that point he would ask the Author to furnish additional data. In some experiments that he had made, which, though few, had been carefully conducted, he had found that the conductivity of a particular sample of copper varied but little, whether it was in the hard-drawn or in the annealed state. Dr. Matthiessen had mentioned that it varied about 2 per cent., but in some recent experiments Sir F. Abel had found that there was no practical difference between the conductivity of certain samples of copper, containing but a small proportion of chemical impurity, when this was in the hard-drawn or the annealed condition. In one experiment, with a length of 15 feet 6 inches of copper, he had obtained 0·0257 ohm resistance with the hard-drawn, and 0·02515 with the annealed. The very slight variations might almost be variations due to experimental error, even though when multiplied upon a statute mile the difference was more appreciable. Taking the numbers upon a mile of wire they would represent, in the case of the hard-drawn wire, 8·707 ohms, and in the case of the annealed wire 8·520 ohms, showing even thus only a very small difference. He might be allowed to allude in passing to what the Author had said in reference to what appeared to be the influence of currents upon the durability of a conductor. Electricians had still much to learn in that direction. Many persons believed that important alterations in the physical struc-

Sir Frederick Abel. ture of copper and of metals generally, were effected by the continuous or intermittent passage of currents through them. He thought, with the Author, that further information was necessary on that point. One thing was worthy of notice, namely, the influence of small quantities of impurities which would be detrimental to copper as a conductor, when contained in the india-rubber or other materials used as dielectric coatings. Minute quantities of sulphur, for example, in india-rubber, would find their way into copper wire-coated with it, and exert a detrimental effect on the metal as a conductor. It was that which led Mr. Hooper to devise the very pretty method—which, however, was only partially successful—of keeping vulcanised india-rubber from direct contact with copper wire-coated with it, by introducing india-rubber between the vulcanised rubber and the copper itself. As to the question of purity of copper, the Author had referred to the very great advantage which had been conferred by improvements in the metallurgical treatment of copper upon the product, so far as electric conductivity was concerned. He had mentioned the "best selected" copper as the material which gave the best forms for wire which could be obtained until certain high qualities of copper were brought from Australia, Lake Superior, and other places. The quality of "best selected" copper, however, was very uncertain, because it was obtained by a somewhat rule of thumb method, and it frequently contained proportions of impurities, detrimental to the conductivity of copper, fully as great as those which had been introduced in the production of some more recent wires, such as phosphor-bronze. One of the important impurities in "best selected copper" was arsenic, and arsenic and phosphorus were about equal in their detrimental effect on the conductivity of copper. He should like some additional information with reference to the statement that electro-deposited copper had not the same mechanical strength as ordinary refined copper. He hardly thought that the Author meant to refer simply to copper in the condition in which it was deposited. Electricians would not attempt to make wires by depositing copper in that form, and he did not see why copper obtained by electrolysis should not be as strong as copper obtained by other methods, because by re-fusing copper in a reducing atmosphere, and then converting it into bar and rolling and drawing it in the ordinary way, it was subject to the same mechanical treatment, and was obtained in the same physical condition, so that, whether it had been originally reduced by electrolysis, or by chemical means, there could be no difference, as far as he could see, in the strength of a wire of a given purity.

Sir Frederick Abel.

With regard to galvanized wires, the Author had pointed out that the durability of iron wire was maintained by galvanizing; and having described the method of treatment, he afterwards stated that the zinc with which the wire was coated became oxidized when exposed to the air, and that, since zinc oxide was insoluble in water, the wire was protected by an impervious coat. There, as a chemist, he must join issue with the Author, though the point was not a very important one. The truth was that oxide of zinc was by no means insoluble, but was actually soluble in soft water, like rain water, to such an extent, that galvanized iron could not be used with advantage as a material for the construction of tanks or conduit pipes where soft water existed, on account of zinc passing into solution, in so considerable a proportion as to exercise an injurious medicinal effect upon the constitution. He thought that when galvanized iron wire was exposed to the air it became coated with a hard film of oxide, such as was formed when a sheet of lead, which was also an oxidizable material, was exposed to atmospheric influences. That hard film protected the metallic coating, and prevented further oxidation; so that the zinc itself was protected by the superficial coat of oxide, which was only very slowly removed by water, the zinc itself remaining as a protective to the metal until the atmosphere plus water found out some minute imperfection in the coating, and then, as soon as the smallest portion of the iron surface was exposed, the action established between the zinc and the iron led to rapid corrosion. That was why, even in the absence of the acid vapours to which the Author referred as destructive to the metal in towns, galvanized iron, not only in the form of wires but applied to other purposes, was uncertain in regard to stability; and there could be no doubt that galvanized iron, though it had been very useful, was on that account a comparatively unreliable material.

He would next refer to an interesting form of conductor, of which those who had to construct military telegraph lines on active service had had considerable experience, namely, the so-called compound wire produced by coating steel wire with a copper sheath, which was soldered to the surface by drawing the steel wire through a bath of tin which acted as a cementing or soldering material. In that way, as the Author had pointed out, a comparatively light and very strong wire of not very high resistance was produced, which presented at first sight important advantages as a conductor; so important indeed did they appear to be that the Royal Engineer authorities, finding the material when first tested to present such great advantages over ordinary iron,

Sir Frederick Abel.

and even over copper wires in many respects, introduced it into the service in some recent campaigns. It was used in the Ashantee and Abyssinian wars, and afterwards in South Africa, and some was even sent to Egypt, though he believed it had been returned thence in the same condition in which it was sent out. The objections advanced against it even as recently as 1881, related simply to its being rather springy, and somewhat difficult to bend, but on the other hand it was found free from the liability to kink, so that the one defect was counterbalanced by the other advantage. But after the material had been in store a few years, and issued again for a special trial at Aldershot, it was found that when attempts were made to put up a line upon which some strain was brought to bear, the wire broke in many points; indeed it broke down utterly, and this was due to the effect pointed out by the Author, namely, that there existed here and there minute imperfections in the building up of the wire, which, admitting the access of water and air, had established a corrosion of the steel wire and brought about the destruction of the material which at first sight presented such important advantages. There was one other disadvantage, namely, that when the wire had been roughly used there was a tendency of the outer sheath to peel off and injure the hands of operators handling it, and to be objectionable in many ways. It was for those reasons that the wire, which had been somewhat extensively used in the service, had been discarded.

The last class of wires to which Mr. Preece had referred were the bronze wires, the first of which was the so-called phosphor-bronze. Any one first applying phosphor-bronze, correctly so called, to the production of a good conductor would be considered very short-sighted, for phosphorus was one of the elementary bodies about the most detrimental to the conductivity of copper that could possibly be used, ranking equal with arsenic in this respect. In some of the early phosphor-bronze wires which he examined, having a resistance of about 49 or 50 ohms to the mile, there existed 0·22 and 0·18 per cent. of phosphorus. But, as the term "bronze" implied, there was always in those wires a certain proportion, but only a very small proportion, of tin. After referring to these new kinds of wires as alloys and as bronzes, the Author stated that phosphor- and silicium-bronze were so called, not so much because those materials were mixed with the copper, but because they were used in the preparation of the alloy, and there was no doubt that to a considerable extent that was the case. Phosphorus was undoubtedly a powerful de-oxidizing agent; and as oxygen was one of the important enemies to the conductivity of copper, the introduction of phosphorus by removing the oxygen would increase the conductivity of the metal or of its alloy with tin. But it was almost impossible to produce a wire from a metal treated with phosphorus without leaving some traces of phosphorus in the material; hence one could quite understand how so-called phosphor-bronze, though superior in point of strength to copper itself, was inferior in regard to conductivity, and was found to be very variable, because it would be exceedingly difficult to produce phosphorized bronze or phosphorized copper at different times containing precisely or approximately the same proportion of phosphorus. The latest form of bronze wire, and the one to which the Author had directed special attention, was the silicium-bronze, to which Sir F. Abel's attention had also been directed when visiting the electric exhibition at Vienna. He there saw the very thin wires now used for telephonic purposes. He had made some experiments with two samples of silicium-bronze wire brought from Vienna, and the results confirmed the statement of the Author that the term silicium-bronze did not at all correctly represent the composition of the material; in point of fact it was not to be assumed that it need contain any silicium at all. In one wire which he examined the amount of silicium was 0·005 per cent., and in another there was not a trace of silicium. It should be observed that in the presence of tin, the proportion of silicium was very liable to be over-estimated, unless special precautionary measures were taken. The first wire was the coarser one used for telegraphic purposes, and it contained 97·75 per cent. of copper, and nearly 0·25 per cent. of tin. The finer wire contained a considerably larger proportion of tin, namely, 3 per cent., and although it was examined with great care, there was no evidence of the existence of silicium at all. Those wires certainly possessed all the properties in regard to strength and powers of elongation and conductivity which were claimed for them; but although it was probable and perhaps certain in the case of one of them that silicium might have been in some way concerned in its production, there was no positive evidence that it derived any valuable quality from the employment of that material, unless it were that, by some special treatment, silicium became in the first instance alloyed with the copper, and by its own subsequent oxidation abstracted the oxygen contained in the alloy, thus removing an antagonist to the conductivity of the material. At any rate it would appear that the electrical qualities and the strength of the wires were chiefly due to the strength of the tin alloy used, and to the metal being employed in a hard-drawn

Sir Frederick Abel.

Sir Frederick Abel.

condition. Both the wires were hard drawn when he received them. The tenacity of the coarser wire was from 300 lbs. to 325 lbs.; its diameter was 2 millimetres, and its weight 100·5 lbs. per mile. After annealing, its tenacity was 190 to 200 lbs.; the finer wire had at first a tenacity of from 170 to 180 lbs., and, when annealed, from 95 to 100 lbs. Although it was possible that silicium might have had something to do with their production, so minute a quantity as was detected by analysis in the one instance might have been purely accidental. It was possible that the chief merit of the process for producing the so-called silicium-bronze lay in the production of a wire consisting almost entirely of pure copper in a hard-drawn condition, but with a small proportion of tin, giving it increased strength. There could be no doubt that pure copper in the hard-drawn condition, with the addition of a small quantity of tin, was a very valuable conductor, and apparently the strongest conductor of this class with which electricians were at present acquainted.

Professor Hughes.

Professor D. E. HUGHES perfectly agreed with Sir Frederick Abel with regard to the use of copper as a standard. His experiments on the molecular conductivity of copper neglected everything as to its chemical composition or its form, and simply regarded the structure of the material. He had a piece of pure copper given him by Prof. Chandler Roberts which he took as a standard, and the conductivity of some of the copper deposited electrically with a Daniell cell was 225, or more than double the standard of the Mint. That value did not perhaps represent the conductivity exactly, but he would say 50 per cent. higher value. It was found that if melted, it fell 50 per cent., and if re-melted it fell again. Whatever was done to change its molecular structure the conductivity fell. He therefore maintained that electrically-deposited copper was the very best form. If a wire could be actually deposited by electricity, it would be in the best form to conduct electricity. But that was not done. It was torn, and pulled, and twisted, and was no longer copper as it ought to be, but some changed conductor. The capabilities of any material in its pure state, and therefore the real standard, were not known. It could not, therefore, be said that the standard of copper was 100. Some experiments had been made by Professor Chandler Roberts and himself on bronze and tin alloy, and it was found that in gradually making the alloys there was a certain point at which a complete and sudden rise in value took place. He wished to ask the Author a question with reference to conductivity. At present, in experimenting for conductivity, they used

Professor Hughes.

a Wheatstone bridge, and took the measure of the electricity after it had been flowing for a minute, or three or four or five minutes, till it had arrived at a stable condition. There was a period for telegraphic purposes which had been called in France the *période variable*, which was not measured, but which was very important for telegraphic instruments when making, say, one thousand contacts per second. There was a great difference between the results with the *période variable* and the *période stable*. If the Author in measuring his wires would use a rapid interrupter, with a Wheatstone bridge having contacts two or three thousand times in a second, he would get some very valuable information of the kind that he required. He did not want to know what it would conduct five minutes after the battery was put on, but what it would conduct during the first portion of the contact. He did not agree with the Author in regard to overhead wires. As an old telegraphic engineer he remembered that the wires were constantly broken. But why did that occur? The Author had himself shown that the zinc became oxidized, and that that particularly occurred in smoky atmospheres. Perhaps he thought that London was not very smoky, and therefore was free from danger. It was stated in the Paper that there was danger, not to the inhabitants, but to the life of the wire itself, and for that reason an effort had been made to get compounds of wire, copper and steel, which gave great promise. It was thought to be an excellent wire at first, but after four or five years its defects were discovered. Indeed the history of telegraph engineering as a whole had been to the present time a history of success; but it had also its history of failures leading on, like the Atlantic cable, to a greater success. Electricians commenced with bad conductors and bad insulators, and then they gradually improved them; but they had not yet attained perfection. The Author now thought that the silicium wire was absolute perfection, and it had the appearance of it; but perhaps in four or five years his opinion might be changed. At present he had no hope for overhead wires except in that form. He had stated that only two persons out of four hundred thousand killed by accident in thirty years had died from injuries received from overhead wires. The wires, however, had not been up during the whole of that time, having increased very rapidly of late years. But the danger from the wires was not at the beginning, it was when they were getting old and shaky; and at such time he confessed he would rather be out of London than in it. It was true that, thirty years ago, Germany as well as England had tried underground wires, failure being the result; but this was in the early period of

Professor Hughes.

telegraphy, and sufficient care was not taken in the manufacture of the cables. Since then, owing to the rapid extension of submarine telegraphy, great experience had been gained, so that the insulation of an underground wire was far better than that of aerial lines. The German Government, after a series of exhaustive experiments, decided upon the trial of a direct underground line from Berlin to Cologne, the success of which had led to a rapid extension in all directions, there being already some 15,000 miles of underground wires. At first their electricians had some difficulty in working these lines at high speed; but in a very short time, by the adoption of the necessary electrical conditions of contacts, reversed currents, and polarized relays, they had been enabled to work their high-speed instruments with far more regularity than was possible with the constantly deranged aerial wires. After mature consideration, the French Government had also lately put their main lines underground, having some 7,000 miles, which would be increased as rapidly as the finances would allow. In Paris as well as in London the telephone companies put their wires overhead; and when he was at the Paris Congress he said it was a great pity that such a beautiful city should be disgraced by overhead wires; that it did not much matter, perhaps, what was done with London, but that there ought to be at least one city free from the evil. All the overhead wires were afterwards taken down. The telephone people protested and declared that the telephones would not work, and that they could not get over the induction. They were, however, forced to put their wires underground, and it was now stated that they were working better than in any other country. Berlin as well as Paris had suppressed all aerial lines in the city; and as the German and French electricians had vanquished all electrical troubles, he had confidence that the Author would equally solve the problem for England.

Mr. Sivewright.

Mr. J. Sivewright, C.M.G., thought there could be no question as to the importance of the subject of the Paper. He could not speak from the point of view of a scientific man, or of a manufacturer of telegraph wire, but he could relate his own experience as a practical man who had to do with electrical conductors, and to whom the objections to the present form of conductor had been forced home nearly every day during the last seven or eight years; and he could from that experience bring forward facts which would go far to support the Author's view as to the extreme desirability of adopting some other form of electrical conductor in preference to iron wire, at all events for aerial lines. He wished to look at

Mr. Sivewright.

the subject from the point of view of a colonial telegraph engineer, because his experience had been drawn from the colony of South Africa, with whose telegraph engineering he had been connected during the period he had named. One of the main items of expense in that colony was transport. It was almost incredible for an Englishman living in a thickly-populated country, and with ample means of conveyance at hand, to appreciate the enormous difficulties in regard to transport in a new country. It might be sufficient to say that the Coal Measures of South Africa were lying practically dormant, and it was found cheaper to import coals from Newcastle than to get them out of the bowels of the earth 100 miles from the sea-coast. Again, tens and hundreds of thousands of acres of splendid arable land were lying waste, and wheat could be imported cheaper from South Australia or from the Peruvian and Chili coasts than it could be brought from the place where the African lands were lying fallow. The cause of the difficulty was transport. The same difficulty applied to the telegraphic engineer in the construction of his lines. If a lighter form of wire were introduced having the same electrical qualities as the iron wire employed at the present day, the transport difficulty would be to some extent overcome. It was not so much the actual saving in the expense between a coil of copper and a coil of iron wire of the same electrical conductivity, although that was considerable; the great point was that the iron wire in telegraph construction was practically the pivot around which the other elements, as it were, revolved. It was what might be called the "independent variable," according to the variations of which all the other materials employed in telegraph construction would also vary. A lighter telegraph wire meant a lighter insulator. Less surface was exposed to the insulator, and consequently a smaller insulator could be used, because there was less leakage. And not only was there less leakage, but in regard to electrical storms, the difficulties which had to be faced were correspondingly diminished. A lighter insulator meant a lighter pole; in fact all the plant of a telegraph line would get proportionately diminished in weight according as the gauge of wire was reduced, and with a reduction in weight followed a reduction in transport, so that a very great saving was effected. The coils of iron wire would be easier to handle, and there would be increased speed in the erection of the wire, attended with diminished cost. As to the question of joints, every one concerned in the maintenance of telegraph lines knew what a bugbear joints were. Whether the wire was copper or phosphor-bronze, or silicium bronze, so long as telegraph engineers

Mr. Sivewright. in the Colonies got light, hard, durable, non-expansive, elastic wire, they did not care. They could get longer coils of it which could be run out to the extent, probably, of 600, 700, or 800 yards, but they were obliged to confine themselves to 500 yards (100 lbs. being about the average weight of the coils); not that manufacturers could not supply longer coils, but that length was found most convenient for handling. If they could dispense with a large number of telegraph joints, they not only saved in that way, but the maintenance became a far easier matter. Those were arguments which, from the colonial telegraph engineer's point of view, he brought forward in favour of reducing the gauge in telegraph wires. One objection that had been brought against the use of copper was that being of greater intrinsic value than iron, it would be more likely to be stolen. That was a specious argument at first sight, but Europeans, at all events, who were inclined to thieve would turn their attention to something more portable and valuable, and less likely to be detected, than the telegraph wire; while the aboriginal had a superstitious and wholesome dread of the wire, so that, in times of peace at any rate, he was hardly likely to meddle with it. Until within the last two years, the South African native respected the telegraph during war, but that respect had now gone, and amongst the difficulties of telegraph maintenance the possibility of the wire being cut and taken away had to be faced. Still he thought that a native, if he had the option, would prefer iron wire during war to copper, because it could be more easily turned into slugs or bullets for his gun. With regard to the effects of galvanizing, he was not opposed to the process; nor would he express any opinion as to its value in countries where the same climatic conditions existed as in England. But he might mention that in South Africa a wire treated as he had described in a bath of oil was erected at least fifteen years ago; it had no galvanizing, but although they had had some splendid specimens erected since, he knew of no better wire than the one to which he had referred. He had examined a considerable proportion of its length within the last twelve months, and he could not detect any flaw or mechanical fracture. It was ordinary soft wire, and had stood well. It was in a dry climate, with comparatively little moisture, with no smoke, and with none of the chemical causes which would affect ordinary wire. What had been said by the Author as to the necessity of rigid inspection almost amounted to a truism, at least he hoped it would be accepted as such; because there was probably no branch of science in which

Mr. Sivewright.

the old proverb was more applicable, "A stitch in time saves nine," than it was in regard to the selection of telegraph materials—not only the wire but all other requisites. Perhaps it required the experience of finding, 300 or 400 miles from the seaboard, insulators open, bolts missing, porcelain gone, iron bases fractured, and telegraph wire breaking in the workman's hands, to realise the enormous importance attaching to a rigid inspection of telegraphic materials. There was not only the value of the wire, but every one knew that if a workman had good material he would make a good job, and if he had bad material he was likely to slur over it. In his opinion, therefore, any administration that neglected so vital a consideration would be guilty of an act that was not only suicidal but criminal.

Professor Huntington.

Professor A. K. HUNTINGTON thought it might be of interest if he gave a few figures with regard to four specimens of silicium-bronze wire which he had recently examined. They consisted practically of nothing but copper, with the exception of a small portion of silicon and tin. In the first coil there was a percentage of 0·099 of silicon, and 0·079 of tin. In the second coil the silicon was 0·117, and the tin 0·0017. In the third coil, silicon 0·1105, tin 0·014. In the fourth coil, silicon 0·0917, tin 0·099. In the second and third coils the amount of tin was so small as to be well within experimental error, so that he was not prepared to say whether the coils really contained tin or not. From the examination of the specimens there was sufficient evidence to lead to the supposition that a certain amount of tin was present, at any rate in two of them. Whether that tin was simply an impurity derived from the ore, or whether it was the residue of tin which had been introduced during the manufacture, he was not prepared to say, as it was impossible to arrive at any conclusion on that point from a chemical examination of the wire. Silicon appeared to be present, and taking into account the supposed process of manufacture, there was no reason to doubt the existence of a certain amount of it. He had mentioned these particulars as bearing out, to some extent, the results given by Sir Frederick Abel, but with some differences in regard to the amount of tin. With reference to the introduction of silicon, he had succeeded in introducing large quantities of that material into copper, and, in some cases, with a very remarkable effect. As to the influence of arsenic on the conductivity of copper, that, of course, was a substance which was one of the greatest culprits in destroying conductivity. But there was another which the Author had not noticed, namely, bismuth, which he thought had even still greater

Professor Huntington. effect than arsenic in reducing the conductivity of copper. One of the countries to which the Author had referred as supplying pure copper, Australia, had ores which contained an appreciable, and, in some cases, a considerable, amount of bismuth; and, as the copper was often sent in ingots, there was liability to trouble with the material so obtained; because, although the bismuth could be removed without difficulty in the "best-selecting" process, due to the relative affinities of copper and bismuth for sulphur, yet in refining, owing to the copper having greater affinity for oxygen than bismuth, it was not practicable to remove the bismuth merely by oxidation, so that if much were present the quantity could be reduced but slightly. That which was removed, so far as he could make out, was due to volatilization. Now, as the copper received from Australia had not been subjected to the "best-selecting" process when in a state of regulus, it followed that it would contain any bismuth originally present in the ore. He had been told by a very large manufacturer that some copper which he had received from Australia, giving by analysis 99·67 per cent. of copper, gave a very bad conductivity—something like 30 as against 90 or 100. The result had been traced to the presence of bismuth. He had found, on further inquiry, that if there was more than 0·05 per cent. of bismuth present in copper its conductivity was seriously reduced.

Mr. Pidgeon. Mr. D. Pidgeon said that the Author had mentioned only to condemn the compound conductors which had been made both in England and in America, and he had condemned equally those of the past and of the present. He did not rise to gainsay this, but simply to bring before the members some examples of the compound conductors now being made in America, and to say a few words with regard to the method of plating in use there. He had had an opportunity during the last spring of passing through the manufactory belonging to the Postal Telegraph Company of New York, at Ansonia in Connecticut, a concern which was making the same wire as that already laid between New York and Chicago. The works were originally erected by Messrs. Wallace and Farmer, of Ansonia, the well-known electricians, for the purpose of carrying out ideas which originated with Mr. Farmer, but they had passed into the hands of the Postal Telegraph Company rather more than a year ago. The works occupied a space of 250 feet square, and there were in the building two hundred and fifty plating vats which were supplied with current by twenty-three dynamos, driven by two engines, each of 300 HP. It would give some idea of the amount of current supplied to

Mr. Pidgeon.

the vats if he stated that he saw a carbon $\frac{7}{16}$ inch in diameter and 10 inches long deflagrated in the course of a few seconds by a shunt so small that its abstraction from the general current could not be noted in the results of the plating. The plating vats were wooden troughs 20 feet long and 2 feet 6 inches either way. Over each plating trough there lay longitudinally a horizontal copper shaft about 3 inches in diameter, from which there hung, like rings from a stick, the coils of wire which were to be plated—as many of them as could be accommodated in the tank, the spires being separated by slips of plate glass, so as to prevent their contact. The balance of the coils hung outside the tank over the end of the shaft. Upon rotation, the coil of wire was screwed slowly through the electrolytic bath, and, after plating, hung again from the spindle, as the unplated wire did at the other end. This operation was repeated three times, the result being that 4,000 lbs. of copper were deposited daily upon 8 miles of wire. He held in his hand a piece of the compound conductor which had been thus three times screwed through the electrolytic bath. It was 0·214 inch in diameter, had a resistance of 1¾ ohm per mile, and a tensile strength of 2,700 lbs., of which the steel contributed 1,700 lbs., and the copper 1,000 lbs. This wire was the same as that through which telephonic speech was readily heard between Chicago and New York, as readily (as he had been informed by a gentleman who listened to it) as if the length had been no greater than that of a room. It was also the wire upon which ten simultaneous messages had been sent—five each way—by means of the well-known Gray harmonic arrangement. It might be said that the wire was very expensive if only 8 miles a day could be produced by the expenditure of such a force as he had mentioned. But the process did not stop at that point. It had been found that the cohesion between the central steel core and the copper envelope was so great that it might be passed through the ordinary wire-drawing apparatus, and the core and the envelope would be reduced together. He exhibited a wire which had been produced from the one he had already shown. This was 12-wire gauge, outside diameter, while the steel core was 18-inch Birmingham wire gauge, and on examination it would be found that the steel core was perfectly central, with the copper surrounding it equally on all sides. Here, then, was a wire the exact equivalent, electrically speaking, of No. 4 iron wire, the largest now used in telegraphy. It could be produced at the rate of 32 miles a day, and the cost, therefore, was one-quarter that of the other. If that conductor came into use it would be, in the first

Mr. Pidgeon. place, because its cost was so much diminished by the fact that it could be wire-drawn, and in the second place because the wire-drawing gave to both wires a considerable increase in their tensional strength, and at the same time secured the conductor against the action of those atmospheric influences which the Author had mentioned in his complaint of previous compound wires. This wire, although a compound one, was as capable of withstanding the attacks of the atmosphere as that of any wire drawn from homogeneous metal. He had a specimen of the joint which was employed in the wire extending between Chicago and New York. It was a copper ferule slightly flattened and tinned by immersion. Into it had been thrust the ends of two wires, and the whole then dipped in a bath. Economically, the wire which he exhibited was the best which the Postal Telegraph Company had yet produced; but he was inclined to doubt whether, even taking into consideration the fact that plated wires could be four or six times increased in length, they could compete with the homogeneous wires of which the Author had shown such extraordinary examples.

Professor Roberts. Professor Chandler Roberts thought there could be no question that pure copper was the best material to employ, because it was well known that a very small quantity of alloying metal caused the curve of conductivity of copper to fall rapidly; and it appeared to him that any increase of tenacity that might attend the union of copper with any other metal, not excepting silver, was dearly bought by the sacrifice of conductivity resulting from alloying the copper, and, as the electrician must have copper as pure as he could get it, any improvement in metallurgical processes for the extraction of copper from its ore assumed considerable importance. There were some facts connected with the electro-deposition of copper which had not been prominently noted in the discussion. He did not think that the scale on which the copper was now deposited electrolytically was quite appreciated. There were two works on the Continent which produced annually at least 500 tons of copper, and there were two works in this country that were being fitted with dynamo-machines that would enable them to deposit copper at the rate of about 60 tons per week. He did not think it was quite understood that nearly pure copper could be thus obtained from very unsatisfactory materials. To take an extreme case there were before him some specimens containing several per cent. of arsenic, and yet by solution and precipitation an excellent variety of copper had been obtained from similar specimens. The Author seemed to fear that electro-deposited copper

Professor Roberts.

did not possess the same tenacity as ordinary copper; but statements had recently been made in the continental scientific journals, especially by Austrian authorities, showing that electrodeposited copper possessed a very high ductility and considerable tenacity. At any rate, the copper was free from metallic impurities, so that even if it had to be melted the metallurgist had only to contend with the question of dissolved cuprous oxide, which after all was a very small matter, because it could be so easily dealt with. Copper was now electrolytically precipitated in bars, rolled directly into rods, and drawn into wire, which found a ready sale at remunerative prices; and it must be remembered that against the extra cost of the solution and precipitation of the copper by electricity there was a handsome set-off, in the shape of the precious metals recovered from the crude metal. He thought, therefore, that the question might be safely left to metallurgists, who would have no difficulty in supplying the electrician with pure copper at a remunerative rate. The Author had asked him to say a few words about the deposit of iron by electrolysis. It was well known that the late Professor Jacobi and Dr. Klein, of St. Petersburg, had taught how to deposit iron of great purity, and with considerable facility. That iron, he was sure, would not compete for electrical purposes with the extraordinarily soft and pure varieties of iron which could now be produced by ordinary metallurgical means. The Author had alluded to the effect produced by silicon in alloy with copper, and it had been stated that $\frac{9}{100}$ per cent. of silicon might be retained by copper. He should like to mention, because he did not think it was very clearly understood, that silicon had an extraordinary effect on many of the alloys of copper. The ordinary alloy of gold and copper containing 90 per cent. of gold fused at about 940° Centigrade, and, if it contained only $\frac{15}{100}$ per cent. of silicon, its melting-point was so much reduced that a strip would bend and fuse in the flame of a candle. Hence it was that the presence of a minute quantity of silicon might be of the greatest importance in modifying the physical constants of pure copper.

He spoke with very little knowledge of the ordinary methods of electrical testing, but he did not think that the extreme delicacy of the induction-balance of Professor Hughes was quite recognised. He had some specimens of copper, which in regard to analysis were identical, and yet when disks of each sample of metal were treated in precisely the same way, mechanically and thermally, they showed a wide difference when submitted to this beautiful instrument, which would be a powerful ally in future, both of the

Professor Roberts. electrician and the metallurgist. The principal point, however, to which he wished to direct attention was, that the metallurgist could supply the electrician with pure copper at a reasonable cost.

Mr. Carson. Mr. W. Carson desired to say a few words with regard to the effect of the presence of manganese, even in small percentages in conductors, upon the conductivity of the material. He had made two samples of puddled iron, from each of which he had obtained a number of tests. The first sample was from a highly manganiferous pig, containing 5 per cent. of manganese. The second contained 3 per cent. of manganese. On being puddled, made into rods, and drawn into wire, the highly manganiferous pig produced an iron containing 98·871 per cent. of metallic iron, and 0·49 per cent. of manganese, with a mile-ohm resistance of 5649·6. The other sample of iron gave 98·89 per cent. of metallic iron in the wire, and only 0·184 of manganese, yet the mile-ohm resistance had risen to 5912·8. He hardly thought that the manganese by itself had much to do with this result. It was worth remarking that the Author's deductions in regard to the presence of manganese were based upon analyses of material under totally different conditions. While samples 1, 2, 3, Table B, were fibrous, the others were crystalline; and the difference in the disposition of the particles must not be overlooked in considering the comparative resistance with the analyses.

Mr. Johnson. Mr. J. Thewlis Johnson said the Author had shown the general improvement in the conductivity of copper wire, and had intimated that the improvements in iron wire had been forced on the makers, who had not sufficiently availed themselves of the services of the chemist. In 1857 a relative of his, with the late Dr. Calvert, made a great many chemical experiments on pig iron, especially as to the changes in pig iron when being converted into wrought iron for wire purposes. The notes were published in the "Philosophical Magazine" in 1857,[1] but the pecuniary results had been very small. Since then some of his friends had, like himself, taken a great deal of pains in conducting chemical experiments, but as far as his own results were concerned they had not been very considerable, and he had come to the conclusion that no iron wire could be made giving a less resistance than what was at present obtained. The difficulty of the iron-wire manufacturer had been to produce a material which would yield certain mechanical and electrical tests. The specifications recently drawn

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[1] Vol. xiv., Fourth Series, p. 165. "On the chemical changes which Pig Iron undergoes during its conversion into Wrought Iron." By F. C. Calvert, hnson.

up were a great improvement on those existing twenty years ago, and the examinations were conducted on a rigorous and fair system. He thought it was generally admitted in the trade that manufacturers all knew what wire would give certain results, and the examining officer in making his tests soon found whether he would be able to pass the wire or not. When he had made a few tests he knew pretty well that if the remainder of the wire was of the same character it would either be all passed or all rejected. No one more than the Author had impressed upon wire-manufacturers the necessity of endeavouring to improve the conductivity of iron. In season and out of season he had urged it upon them, and the result was that they were now all producing an iron which gave, ton for ton, a better average of conductivity or a less resistance than was obtained twenty years ago. But he wished to direct attention to the fact that while it was perfectly true that the iron wire used in England had decreased in resistance from about 15½ ohms in 1873 to 11¼ in 1883, low resistance wire had been a regular article of commerce long previously. He knew that in 1862 some 2,000 miles of wire were sent from England to the French Telegraph Administration, and it was identically the same as that now used by the English Post Office. In the specification of the French Telegraph Administration in 1862 there was no stipulation as to the conductivity of the wire; but it was stipulated that the wire should be manufactured in a particular way, which gave certain high mechanical tests, and also the conductivity tests which the Post Office now demanded. He could give many other instances, but he would only mention the line crossing the continent of Australia, erected in 1871. It was an unfortunate thing for the credit of England that the introduction of the conductivity test in the specifications, although advocated so long by the Author, did not first take place in England, but in America, by the Western Union Telegraph Company. He hoped the members would not leave with the impression that the days of iron wire as an electrical conductor were numbered. He had listened with great interest to the remarks on the process of depositing copper on steel, and he had been astonished by the statement that during the process of drawing wire when the copper was deposited on the steel the diameters of the steel and the copper were reduced equally. But for that statement he should certainly have doubted the fact. He believed that in practice it would be found that the deposited copper-coating would occasionally break in the process of drawing, and further, that as wire when drawn down became harder, and had to be annealed before the process could be re-

Mr. Johnson.

Mr. Johnson. peated, a difficulty might arise in annealing a compound wire composed of steel and copper. The experiments with phosphor-bronze wire and compound wire, according to the Author, had not resulted satisfactorily, and there were only two other conductors, both of which were so expensive that economy compelled them to be used with a very small diameter. It was asserted that No. 14 copper wire, costing £87 a ton, was as efficient a conductor as No. 8 iron wire, costing £20, and that, mile for mile, it was not more expensive. That might be so, but he questioned whether it would be found as economical in practice. He thought that when it was scattered all over the country a good deal would be stolen. At Vienna there had been a large exhibit of silicium-bronze, the cost of which he was told was £162 a ton. It appeared to him that it would make a very charming toy line. It was never used till November 1881, when the first quantity was sent by the French manufacturer to the Austrian Telegraph Administration for an experiment. He had seen no statistics as to its life. In India, monkeys often sat on the wires, and in the Colonies the birds flew against them, and he did not see, under such circumstances, how telegraph wires were to be maintained if they had only the diameter of pins and needles. Whatever conductors were employed, he thought they ought to have a good substantial diameter if the lines were to be maintained for any length of time.

Mr. Bolton. Mr. A. S. Bolton exhibited some samples to show the process of manufacturing copper wire. The Author had referred to the rapid strides which had been made in improving the quality of conductors for electric currents, but these had also been greatly improved in form. It was often a great advantage to the electrical engineer to have the conductors of great length, and that object had now been accomplished. In 1850, when Mr. Charlton J. Wollaston, the electrical engineer of the experimental cable laid between Dover and Calais, came to his office with the order for the copper wire for the core of the cable, he was imperative that it should be made in continuous lengths to weigh about 30 lbs. in each piece. At that time, the only wire produced in copper of that size weighed about 4 lbs. in continuous length; and the foreman who was sent for to receive instructions, when he heard what was required, said, "Does the man think I am a fool?"—so impossible did he consider its production. At the present time continuous lengths were commonly made, with copper wire of the same diameter, weighing 70 or 80 lbs. The Author had stated that conductors for cables and electric light mains should be constructed with the purest copper producible. That object had been

Mr. Bolton.

attained, and the samples on the table tested over 99 per cent. by Matthiessen's standard. With regard to aerial lines there might be some question. The Author had stated that for such lines a great tensile strength should be combined with very high conductivity. In his own works it had been found that in attempting to improve the tensile strength by introducing any foreign substance into the pure copper there was a loss of conductivity. The 14-gauge hardened-copper wire with high conductivity gave a breaking-strain of 340 lbs., and a resistance of only 8 ohms to the mile; the weight per mile was 103 lbs., and the cost about £4. A wire, 15 gauge, which had a resistance of 10¾ ohms per mile, had a breaking strain of 255 lbs., and the cost was only 65*s.*—about the same as that of ordinary iron telegraph wire 0·171 size. It would be seen from the Table of the Author's experiments with silicious bronze, that the 0·081 wire, with a resistance of 8½ ohms per mile, gave only about an equal breaking-strain to that of hardened copper of the same gauge, and the cost was about £6 per mile. It appeared, therefore, that hardened-wire of high conductivity answered all the ends, and the breaking-strain was a very good one, 340 lbs. being sufficient for all purposes. The objection to the introduction of phosphorus or other materials was, that results were never uniform; but with wire of high conductivity the results were always exactly the same. When silicon was introduced conductivity was wanting. The Author's next requirement was a low inductive capacity. That, he believed, would only apply to cables or insulated wires placed underground. Next that the conductors should expose to wind and snow the least possible surface. Of course the lower the resistance the less the diameter of wire necessary to pass the same current, and therefore the wire of high conductivity would seem best to accomplish that end. The last requirement was that the wire should be practically indestructible. In that respect he thought that copper had everything in its favour. He might instance the case of a wire that had been more than twenty years over his own works; it had been constantly used for the passing of electric currents, and it had not altered in its conductivity or in its diameter during that period. As to coating steel wire with copper, and then drawing it down to make a conductor, reducing the diameter both of the steel and the copper, he too was much astonished. In his own works it was a common thing to put a steel mandrel inside a copper tube, and to draw the tube down; but the mandrel always remained the same diameter. He could hardly understand how the result that had been stated could be

Mr. Bolton. possible. To get wire of high conductivity it was essential that the ores, or the copper bars imported from Chili should contain as few alloys as possible, as then there was not much oxidizing required in the refining process. The copper was cast in large bars (of one of which he held in his hand a section). These were rolled into long strips like the specimen exhibited, and then passed through a series of circular steel cutters, which cut them longitudinally into narrow pieces, each of which was passed edgeways through grooved rolls, forming a nearly circular bar of copper, which was subsequently drawn down to wire of the required size. The process was different from the manufacture of iron wire, which was not slit but rolled down into a thin rod from a large bar. He also exhibited some specimens of hardened copper wires which had been subjected to different tensile strains, showing the diminution that had taken place in size, but they generally secured a breaking-strain of 340 lbs., which was found to be practically sufficient.

Sir Frederick Bramwell. Sir FREDERICK BRAMWELL, Vice-President, said it appeared Mr. Bolton, like Mr. Johnson, was surprised that the two metals in a steel wire, coated with copper, when drawn should draw uniformly, and in support of his doubts had referred to the fact that, if a steel mandrel were put inside a copper tube, there was no elongation of the mandrel when the two were drawn together. That was perfectly true; but it should be remembered that in that case there was no metallic attachment of the mandrel to the tube. He wished to remind the meeting of a cognate instance in rolling —that when lead and tin were cast together in two thicknesses, to make Dobb's metal—it was formerly alleged that these two metals would not roll out uniformly; but, as a matter of fact, in whatever proportions they were cast—3 to 1, or 4 to 1—the rolled-out sheet showed the same proportion, although the metals were so dissimilar in their powers of yielding under the roll.

Mr. Rock. Mr. JAMES ROCK said he should like, as representing a company which manufactured both phosphor-bronze and silicium-bronze, to say a few words on the subject under discussion. With reference to the uniformity of manufacture of alloys of copper, especially with silicon and phosphorus, it was part of the process of his company to manufacture those metals in strictly uniform proportions, and he could answer for the uniformity of the products as well as Mr. Bolton could for that of the copper which he had produced of such excellent quality. The French manufacturer of silicium-bronze, who was also the inventor, supplied large quantities to the French and other Continental Governments, and he guaranteed and produced it of certain degrees of conductivity and tensile strength. So far from silicium-bronze being at present only a toy, on the Continent it was interfering largely with the use of iron wire for telegraphs. That was not the case in England, because the material was comparatively new. The analyses of Sir F. Abel and Professor Huntington confirmed the analyses in his own possession of similar alloys. There was, however, an apparent discrepancy with regard to the quantity of tin in the specimens. It was part of the process of manufacture that the proportions of tin and silicium should be adapted to the special uses for which the wire was intended. They accordingly produced two special kinds of electric conductors, one of high conductivity for telegraphs, and one of lower conductivity, but much greater strength, for telephones. The wire for telephones was largely used in England. It had very great tensile strength —as great as that referred to by the Author in connection with the telegraph wires for the Mumbles. It had similar properties to those wires, but a much higher conductivity; instead of 20 per cent., it had from 36 to 40 per cent. The apparent discrepancy between Sir F. Abel and Professor Huntington was probably due to their having analysed examples of different constitution, one the telephone wire, and the other the telegraph wire. It was possible to produce silicium-bronze of different degrees of conductivity and of tensile strength. If electricians and engineers would only say what amount of strength and conductivity they required, the proportions could be adjusted accordingly. The product was a very valuable one, and the analysis of one specimen should not be taken as representing silicium-bronze generally. Mr. Rock.

Mr. Frederick Smith observed that the manufacturers of iron wire had not failed to make use of the services of chemists in endeavouring to improve that material. It should be borne in mind that the manufacturers of copper had a very different material to deal with at the outset, and the same advance therefore ought hardly to be expected from iron-wire manufacturers. Great progress, however, had been made, and he thought that the resources of civilization were not yet exhausted even in the improvement of iron or steel wire. He had been testing some samples of an English made steel wire, which gave as high a degree of conductivity as those of any Swedish charcoal iron he had tested, together with a much greater breaking-strain, and a higher degree of torsion. The six samples yielded the following results:—Diameter 209, resistance, 8·13 ohms; dia- Mr. Smith.

Mr. Smith. meter 208, resistance, 8·79 ohms; diameter 208, resistance, 7·98 ohms; diameter 209, resistance, 7·23 ohms; diameter 209, resistance, 7·74 ohms; diameter 209, resistance, 7·98 ohms. The samples were all tested in the bright hard state previous to galvanizing. After galvanizing, the improvement would be about 0·3 ohm per mile in each case. That was practically a new material. All who had worked for the specification for which the wire was used would know that a practically new material had to be made in order to meet the requirements. Instead of taking a material that already possessed a high degree of conductivity, the manufacturers had to take a material that gave a very great degree of resistance, and to bring it up to a high degree of conductivity; and they could only do that by making use of the services of chemists. With reference to the adoption of copper and phosphor-bronze or silicium-bronze, it should be borne in mind that a telegraph wire had a double function to perform. If it was simply a conductor and had only to carry the current, the wire with the highest degree of conductivity would undoubtedly be the best to employ; but the wire had not only to carry the current, it had to carry itself; it had to be out in all weathers, over very long distances, through all kinds of country, and it had to encounter all kinds of risks. It was necessary, therefore, that it should have a certain amount of bulk. Much had been said about wires breaking down, but if wire was used of the kind that had been so highly praised, he thought the number of breakages in all parts of the country would be greatly increased. He had recently tested a sample of hard-drawn copper wire, and had found that the mechanical properties were inferior; it would not stand wrapping and unwrapping round its own diameter without breaking. That was a test which all hard wires ought to stand. The material bore only about ½ per cent. elongation, which an inspector would put down as nil, after allowing for the fracture itself. The breaking strain also was very slight, and it would only allow fourteen twists in 6 inches. The size of wire that he tested was 0·81, about No. 14 W. G., which was about one-quarter of the weight of iron wire of the same conductivity. Instead, therefore, of being only four times the cost, as might be expected, it was eight times the cost, consequently the cost of the line made of copper would be twice that of a line made of iron-wire, so far as the wire was concerned. It was also exposed to great risk from the slightest motion of the posts, and any substance thrown against it caused it to break immediately. In hot countries, where perhaps the wire would be most used in consequence of the great cost of transport, the results of changes in temperature might be very serious. The sun was very hot by day, and the nights were often cold, and the wire would not possess sufficient ductility to stand such changes in temperature, which might cause it to snap. Mr. Johnson appeared to think that in the manufacture of compound wire, the steel would not be reduced at the same time as the copper or to the same extent. He might be permitted to remind him that it was the custom amongst wire-drawers to draw wire coated with tin, and both were reduced at the same time without the tin being removed by contact with the draw-plate. If so soft a metal as tin could be so treated he thought that copper would bear the same kind of treatment. Mr. Smith.

Mr. J. H. Greener had been connected with telegraph works for nearly forty years, and most of his time had been spent in erecting lines and supervising stores for different administrations. Meanwhile great improvements had been made on all sides. He was glad of the opportunity of speaking of iron wire before it became a thing of the past, which seemed to be the hope of the manufacturers of copper and bronze. Twenty years ago iron wire weighing 600 lbs. to the mile would not bear the strain of 1,000 lbs. without breaking. In the present day, with the same wire, a breaking strain of 2,000 lbs. could easily be obtained. The Post Office specification required a wire of very fine material, almost pure iron, because, working as they did duplex and quadruplex, the authorities wanted high conductivity. The specification for the India Office required for a wire of the same size 350 lbs. more breaking strain. The extra breaking strain had been a great bugbear to the wire-manufacturers. They could easily give the 350 lbs. additional breaking strain, and also the capability of sustaining fifteen twists in a length of 6 inches, but when the conductivity test was also applied they had a very difficult task to perform. It had been accomplished, but to effect this the aid of the chemist had to be called in, because the wire manufacturers found that it would not pay to go on with the rule of thumb methods previously in use. He had with him some tests of the wire made by different firms during the past year. In the wire made by No. 1 firm, the average breaking strain was 2,196 lbs.; No. 2, 2,123 lbs.; No. 3, 2,150 lbs.; No. 4, 2,195 lbs. This uniformity was astonishing. Those results had not been achieved without a great deal of hard work, worry, and anxiety on the part of the manufacturers, who, in carrying out the specifications, had always been willing to render every possible assistance. Mr. Greener.

Mr. Hedges. No doubt they had often thought him a great nuisance, but they had certainly helped him in every possible way.

Mr. KILLINGWORTH HEDGES desired to say a few words on the effect of powerful lighting currents through a copper conductor. It was most important that engineers who had to do with electric lighting, and local authorities who proposed to purchase expensive copper cables and lay them down to distribute electricity in their districts, should be certain that the passage of a powerful current had no effect on the conductivity of the wire. He had noticed, as mentioned by the Author, that wires taken from dynamo-machines, especially those which had an alternating current passing through them, became brittle. He had thought it might be interesting to ascertain whether there was any change in an ordinary commercial cable which had been carrying a current of electricity for some time, and he had for this purpose tested a cable through which a current had been flowing for nine months, say about sixteen hundred working hours. The electromotive force was 1,000 volts, the size of the cable 7 strands, No. 16 B. W. G., and the current 10 amperes. He tested the resistance carefully, and compared it with that of a cable of similar design which had never been used, and he could find no difference. He then had the fracture examined microscopically, and he could detect no signs of brittleness. The cable had only been working a comparatively short time, and the current therefore was very small in proportion to the area, about one-fourth of what the maximum current might have been as allowed by the Board of Trade, 2,000 amperes per square inch of section. If a larger current had been used there would probably have been some heating, as Dr. Matthiessen, in his contribution to the Royal Society,[1] had shown that if heating took place in a copper cable of a certain degree of impurity, there was an alteration in its conductivity, and he had quoted the case of a very impure piece of copper, which increased in resistance 0·064 per cent., after being heated to 100° Centigrade for three days. Dr. Matthiessen's experiments only went as high as 100° Centigrade, but Mr. Hedges thought he would go as high as he could in heating various wires of pure metals and alloys by a current of a secondary battery, and the results were stated in the annexed Table. The first column showed the material used; the second, the resistance before heating; the third, the decrease of resistance after heating; and the fourth, the approximate temperature as nearly as it could

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[1] Phil Trans. 1864, vol. 154, p. 167.

Mr. Hedges.

Materials.	Resistance.		
	Before Heating.	Decrease after 24 Hours.	Temperature. Fahrenheit.
No. 1. Tin wire	0·815	0·003	390°
„ 2. Lead	0·835	0·005 in 3 hours	590
„ 3. Tin alloy	0·870	0·005	490
„ 4. Copper	0·810	No change	1,900
„ 5. Tin-foil	0·860	„	400
„ 6. Albo alloy	0·835	„	1,200

be obtained. The experiments tended to show that the pure metals underwent no change in resistance after being heated twenty-four hours; but those containing some commercial impurity decreased in their resistance and increased in conductivity. The decrease was very small, and was most noticeable in No. 3, the tin alloy, to which he desired to draw attention. The experiment in that case was only carried on for three hours, by which time the conductivity had increased 7 per cent. He could not carry it on longer because the alloy melted, probably by the decrease in resistance allowing a larger amount of current to pass. This alloy (tin and lead) was well known in the form of solder, which was largely used for jointing electric-light wires. It was dangerous to rely on solder alone because it would be softened by the passage of the current if there was any heat caused by a slightly imperfect joint, and an action would then go on which he thought had a tendency to reduce the metals into their constituent parts, so that by degrees the two wires would come a little apart, an arc would be formed, and the joint destroyed. All joints for electric lighting purposes ought to be made mechanical under considerable pressure, the solder should only be used to keep away the air. It would be interesting if the Author would give his experience of the joints used by the Post Office, also whether there had been any variation in resistance after they had been employed a long time. The question of joints was most important for electric lighting. Dynamo-machines afforded a most economical method of transforming mechanical work into electricity, and the problem of using the current of electricity and distributing it successfully appeared to him to be in the cost and the efficiency of the conductors and their joints. Now it was required in a perfect conductor that the current in its passage should develop no heat until it arrived at the lamps, where the heat would be utilized in the form of light. The Author had

Mr. Hedges. suggested a possible variation of resistance due to temperature of 20 per cent. between summer and winter. He hardly thought that would be the case in England. In some climates perhaps there might be that amount of variation if overhead wires were used for electric lighting purposes, but if they were placed underground he did not think they would be subject to as much variation in temperature as were ordinary gas- and water-pipes, in that they would be surrounded and carefully insulated by some material which not only was an insulator of electricity but a non-conductor of heat.

Mr. Blakesley. Mr. T. H. BLAKESLEY considered that in view of the large outlay which would probably take place in conductors for the distribution of electricity for electric lighting or other purposes, the Author had passed rather hurriedly over the law of economy which Sir William Thomson was the first to suggest.[1] He ventured to recall the attention of the Institution to that point, first because of its great importance, secondly because the Author had somewhat imperfectly quoted the law, and thirdly because that economy was in practice very rarely carried out, it being generally thought advisable to save present outlay at the expense of future current expenses. The problem, of course, was analogous to the one which engineers constantly had to encounter in pumping through hydraulic mains. If the main was contracted too much, there was a saving in the expense of pipes but a loss in the current expense of pumping. There were two forms of the law usually given, one that which had been stated by the Author, and the other asserting that the current should be always proportioned to the sectional area of the conductor. Both statements were somewhat imperfect, and were, moreover, very often misapplied. Sir William Thomson arrived at a result giving about 322 amperes to the square inch of conductor of copper, when the price of the copper was £70 a ton and 5 per cent. interest was allowed on the outlay, and the time during which the current flowed was one-half, or twelve hours a day. The late Sir William Siemens, in his address before the Society of Arts,[2] arrived at the value of 390 amperes per square inch, taking £90 as the value of copper per ton and 7½ per cent. interest on the outlay, and one-third of a day, or eight hours in twenty-four, as the time of working. All these changes tended in the same direction. Now 390 did not materially differ from 324, and even one of the alterations which

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[1] "British Association Report for 1881," p. 517.

[2] "Journal of the Society of Arts," November 17, 1882, p. 6.

Mr. Blakesley.

he made was sufficient to account for the difference. The reason why the divergence was so small was that he had put the cost of energy at 12*d.* per 10 Board of Trade units, which most people thought very high. He had used what would correspond more to the price of energy than to the prime cost; but in that problem no doubt the prime cost was the thing that should be taken into consideration. But whatever the values of these quantities, Sir William Thomson's law was only applicable to conductors where the expense of the conductor varied with the weight of it. No doubt in telegraph wires that was approximately the case; but in the distribution of electricity on a large scale for electric-lighting purposes, or for the transmission of energy, the conductors were insulated, and probably underground, and on comparing the price of a bare conductor with its cost when highly insulated, it would be found that the price of the insulation was in excess of that of the conductor itself, for ordinary conductors, say of a ½ square inch section, and that the extra expense of insulation did not vary anything like according to the section of the conductor, but more nearly as the diameter of the wire, or as the virtual diameter in the case of a bundle of wires. That would greatly modify the law as usually quoted for a proper economical system. One outcome of the calculation in this case was that there was no longer the constancy between the current to be carried, and the sectional area to carry it, which was so often quoted. Another outcome was that the number of amperes that might be put through a square inch was much higher than that given by Sir William Thomson or by Sir William Siemens. He had ascertained from the prices of a well-known manufacturer, that, with a conductor thoroughly insulated with gutta-percha and covered with jute and tape in section ½ square inch, and employed for twelve hours in twenty-four throughout the year, there ought to be 566 amperes per square inch passing through it; for less sections of conductor more could be put through a unit of section. This rate per square inch increased sensibly, though not largely, as the section got smaller.

Mr. Preece.

Mr. W. H. Preece, in reply, observed that Sir Frederick Abel questioned the difference said to be found between the conductivity of hard-drawn and soft copper; but his own figures showed that it was 2 per cent. in favour of the latter, and this corroborated the accepted figure. He still maintained that iron manufacturers had not sufficiently brought to their aid the talents of the chemist. At the present time they absolutely did not know what was the conductivity of pure iron. Professor Chandler Roberts had kindly

Mr. Preece. offered to supply him with a piece of pure iron, but it was not certain that he had a piece to supply. Indeed, he did not know that a piece of pure iron had ever been seen. If anybody would supply electricians with absolutely pure iron, they would be delighted; at present they did not know what resistance it gave. It was true that Professor Hughes, with his exquisite little instrument, had told some curious stories about the internal arrangement of molecules, and he was prepared to assert that certain specimens were 225 times better than certain other specimens. He had not mentioned, however, how to obtain iron of sufficient purity to make perfect magnets and perfect wires. On the question of iron bars and copper wires, Professor Hughes had suggested that the probability was that after five years' experience copper wire would be rejected, just as compound wire had been. In England the requisite five years' experience had been obtained; and electricians certainly had not arrived at the conclusion that copper was a better conductor for overground purposes than iron, without long experience and very rigid practical tests. They now had copper wire not in pounds or in miles, but in hundreds of miles scattered over the country, and the result of their experience had been to show that for certain purposes (he did not say for all) copper had a greater superiority over iron than some of the speakers would be inclined to believe. Mr. Johnson appeared to think that copper would be stolen, but that had not been the result of past experience. As to monkeys climbing upon wires, those animals, like iron-wire manufacturers, had increased in intelligence. In the early days of telegraphy they did climb upon the wires and break them down, but they did not do so now. Perhaps the difference was due to the fact that the first telegraph wires were made of thick iron rods, while the more recent wires were much finer, and the finer they were the less likely monkeys might be to perform gymnastics upon them. He was sorry that Professor Hughes differed from him on the subject of overhead wires. He believed that all electricians were agreed upon one point, that whatever the merits or demerits of overhead wires, they were better adapted for high-speed apparatus and general telegraph work. There could be no doubt that if a wire were extended between London and Manchester it would be commercially sixteen times worse underground than above ground; and to try and force an Administration like the Post Office to put its wires underground, because of some imaginary danger, was as absurd as it would be to try and force every Railway Company to tunnel underneath the roads instead of crossing them by bridges.

Mr. Preece.

It had been said that overhead wires were dangerous, but, as he had asked before, where was the danger? There was much more danger in opening trenches. The number of accidents from the latter cause very far exceeded those from falling wires. As to the question of economy, those who had to spend the money were, he thought, the best judges on that point. His remarks, however, applied to outlying districts. The parish of Wandsworth, for instance, wanted a fire telegraph and a police telegraph; the Post Office authorities wished to put the wires overhead, and the Wandsworth Board tried to force them to put them underground: the postal authorities had resisted, and the matter was now before a Court of law. The opposition raised in many of the outlying districts against overhead wires was, he considered, a senseless proceeding; it meant additional expense, and it did not remove danger. Who cared about the appearance of wires in a country district? No doubt many of the streets in London would be considerably beautified if some of the numerous wires were removed; his remarks, however, did not apply to the City of London, but only to outlying districts. What local authorities needed was power to control the erection of overhead wires, not necessarily power to forbid their erection. In all large cities and towns the Post Office put the wires underground, not to diminish danger, nor to improve appearances, but for convenience and economy; they had even an underground line between Liverpool and Manchester. Wherever it was necessary the lines were put underground, but they did not intend to put them there unless it was absolutely necessary, and they were not to be forced to do so by any absurd mania on the part of the local authorities. The important question of joints had been raised by Mr. Hedges; but there was one that had been settled long ago by telegraphists, it was, that the telegraphic joint as now constructed was perfect. In his long experience of thirty years, and he could appeal to those who could speak of a still longer period, the existence of a bad joint in a line properly constructed by an experienced man was absolutely unknown. He had seen, however, in lines used for electric lighting, most inefficient joints, and it was a matter of surprise that many of the electrically lighted public buildings had not been destroyed by the utterly unsuitable wires that had been employed. There had been serious accidents, and there would be more unless electric-lighting engineers took a little more to heart the lessons of experience on this point. He had been contented with quoting in its broadest sense Sir William Thomson's law, leaving the results to be worked out by those who

Mr. Preece. wished to apply it, and who possessed the current prices of materials. The subject had been more fully worked out by Mr. T. Gray.[1] He however agreed with Mr. Blakesley, that the number of amperes per sectional area which could be transmitted with safety and economy was greater than that given by Sir W. Thomson and the late Sir W. Siemens.

Sir J. W. Bazalgette. Sir J. W. Bazalgette, President, said that the Paper had led to a very practical discussion. There had been a healthy rivalry between the manufacturers of iron and copper wire, and if, as the Author had pointed out, those gentlemen would call in the aid of the chemist, the result would be that conductors would be greatly improved both in regard to conductivity, strength, and cheapness. He might mention that he had just received a message through an electric conductor, stating that communication had been that day established between the two ends of the tunnel under the Mersey.

Correspondence.

Mr. Atkinson. Mr. W. Atkinson concurred with the Author in thinking it desirable that iron electrical conductors should be covered with zinc, notwithstanding zinc was readily dissolved in soft water. He might mention some observations that had been made, and experiments tried, with the hope of harmonising opposing views. A galvanized iron roof exposed for fifteen years still retained the mottled markings of a new plate, though in a less degree. The inside of a galvanized iron cistern, after containing water supplied by the Lambeth Company for eighteen years, was in good condition, though there was a visible formation of the carbonate of zinc on that part to which the water did not reach, or only very rarely. Zinc exposed to the air for some time, and that had lost its brightness, had one side rubbed with emery cloth, and was then placed in a bottle of boiled rain-water, and the bottle was then corked. After one hundred and twenty hours no action had taken place. A similar strip was placed in unboiled rain-water in the same way in every respect, and the polished side was covered with a very fine and uniform film of white matter, no doubt the carbonate or oxi-carbonate of zinc. On the other side there was also a slight whiteness. Another strip was placed in rain-water in an open vessel, and there was a considerable formation of the carbonate on the polished side, at and just below the

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[1] Philosophical Magazine, 1883, vol. xvi., 5th series, p. 187.

Mr. Atkinson.

water-level, and some, but much less, on the side that had not been recently polished. Another strip was placed in the Lambeth Company's water in an open vessel, and on the polished side there was a marked formation of the carbonate, but on the unpolished only a faint whitening of the surface. Hence it seemed evident that the clean surface of zinc was acted on both by hard and soft water when carbonic acid was present, but that no action took place when it was absent. Also that when zinc had been exposed to the air for a considerable period, its surface was so altered by oxidation or otherwise, that it was only slightly affected by rain falling on and running over it.

Mr. Jamieson.

Mr. A. Jamieson observed that the Author had referred to Matthiessen's standard resistance, namely, "100 inches, weighing 100 grains, giving 0·1516 ohm at 60° Fahrenheit," as well as the specific resistances—

1 metre	weighing	1 gram	=	0·144	ohm	at 0° C.
1 foot	„	1 grain	=	0·2064	„	„
1 knot	„	1 pound	=	1091·22	„	„
1 mile	„	„	=	842	„	„

These results of Matthiessen's were not, however, in true ohms, as represented by the Author, but in the B. A. units as published by the British Association Committee on Electrical Standards in 1864. To reduce them to Lord Raleigh's determination in October 1882, namely, "one B. A. unit = 0·9865 of the true ohm,"[1] each of the above values had therefore to be lessened by 1·35 per cent. This correction, small as it might appear when applied to the standard length-weights metre-gramme and foot-grain, reduced the knot-pound from 1091·22 B. A. units to 1076·49 ohms, or a difference of 14·73 ohms. Many careful experimenters were having their resistance coils corrected to Lord Rayleigh's value of the ohm. Another point worthy of attention was this, that the values mentioned by the Author were for pure annealed copper wire, which was seldom met with in practice; it was better, therefore, to take the specific resistances in ohms (B. A. unit results corrected) of hard-drawn pure copper wire when dealing

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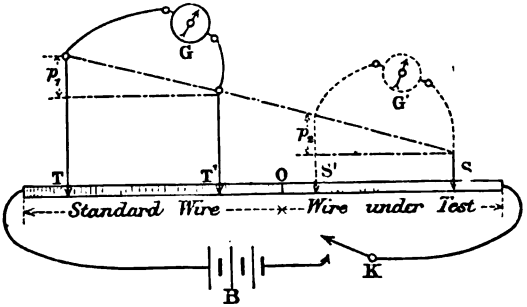
[1] A mean of three series of experiments carried out at the Cavendish Laboratory in 1882, by the method of Lorentz, gave 0·98677 ($\times 10^9$ C. G. S.) = 1 B. A. unit, which would amount to a reduction of 1·32 per cent. in converting from B. A. units to true ohms. The Units Committee will probably issue, after their meeting in April next at the Congress in Paris, a definite "determination." —A. J.

Mr. Jamieson. with telegraphic or electric light measurements. For example, 1 metre of copper weighing 1 gram = 0·1469 B. A. unit = 0·1449 ohm at 0° Centigrade. The Author said that "the test for purity is extremely simple;" but, although he gave the formula by which the results, when obtained, might be used for finding the percentage purity of any wire, he did not indicate which was the easiest and most accurate test to employ. If a specimen of but 2 or 3 feet of thick wire were handed to an electrician with the request that he would determine its percentage purity, the resistance was so small that the ordinary Wheatstone Bridge methods with resistance coils were useless, and recourse must be had to Sir William Thomson's Wheatstone Bridge arrangement, or Messrs. Matthiessen and Hockin's modification thereof, with Kirchoff's bridge wire, or to the difference of potential method, which was by far the simplest of application and needed but little apparatus. As it was not as yet well known to engineers, and its application to the measurement of short lengths of thick wire or very low resistances had not yet been recorded in text-books, it might be well to mention it. Sir William Thomson had recently designed a mhometer for obtaining the conductivities or "mhos" $\left(\frac{1}{\text{ohm}}\right)$, or the reciprocal of very low resistances.[1]



DIFFERENCE OF POTENTIAL TESTS FOR SMALL RESISTANCES.

1. Join a standard wire of known resistance or percentage purity by a good metallic connection at O to the wire to be tested, and put them in circuit with a constant battery B by a key K.

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[1] "Electrical Pocket Book." By Munro and Jamieson, p. 95.

Mr. Jamieson.

2. Mark off on the standard wire a certain length T T′ (say 100 inches or 100 centimetres), and apply the electrodes of a quadrant electrometer to T and T′, or mirror galvanometer of high resistance, compared with the wires under test, and note the deflection d_1 due to the difference of potential p_1 between these points.

3. Switch the electrometer or galvanometer quickly into the position G′, and note the deflection, d_2, due to the difference of potential p_2 between points S and S′, and if possible so adjust the lengths T T′ and S S′ that the deflections d_1 and d_2 are equal.

Then, if the sectional areas of the standard wire and the wire under test are the same—

$$\overset{\text{Length.}}{T\,T'} : \overset{\text{Length.}}{S\,S'} :: 100 : y = \text{the percentage purity of the wire under test as compared with the standard wire.}$$

But if the wires are of different sectional area, let A be the cross area of the standard wire, and A′ that of the other.

Then T T′ : S S′ : : 100 : y = percentage conductivity required;
and A′ : A.

Example: 100 inches of pure copper No. 16 in circuit with a copper wire, 55 inches of No. 18 wire when deflection $d_1 = d_2$, what is the percentage conductivity of the No. 18 wire?

Here T T′ = 100 inches, S S′ = 55 inches, A = 0·0033 square inch, and A′ = 0·0019 square inch;
∴ 100 : 55 : : 100 : y = 95·5 per cent. purity.
and 0·0019 : 0·0033.

The Author omitted to mention the properties of aluminium and aluminium-bronze wires. From some experiments which Mr. Jamieson had been carrying out lately on these wires, it appeared that the former, from its extreme lightness, might be used for military telegraphic purposes, where weight and bulk of bag and baggage played such an important part, while the latter aluminium-bronze seemed admirably adopted for high resistance coils under certain circumstances, for it had about double the resistance of German silver for the same length and area. He was still engaged on these tests, and herewith sent those of two of the first samples that came to hand, but he was in hopes of getting still better results from others which had just arrived.

Mr. Jamieson.

Tests of Aluminium and Annealed Copper Wire.

Taken at the College of Science and Arts, Glasgow, December 1883.

1. Chemical tests by Dr. Clark, F.C.S., &c.

Copper, sp. gr. . . . = 8·822	Per cent.
Copper	99·99
Arsenic	0·01
	100·00

Weight per cubic foot = 550 lbs.

French aluminium, sp. gr. = 2·736	Per cent.
Aluminium	98·39
Iron	1·24
Silicon	0·37
	100·00

Weight per cubic foot = 170·6 lbs.

$$\text{Ratio of weights, } \frac{\text{copper}}{\text{aluminium}} = \frac{3 \cdot 225}{1}.$$

2. Electrical Tests by A. Jamieson, F.R.S.E. Temperature 59° Fahrenheit.

—	Diameter.		Weight and Length.		Resistance and Length.	
	Millimetre.	Inch.	Grains per Foot.	Lbs. per Mile.	Ohm per Foot.	Ohms per Mile.
Copper wire . .	2·413	0·095	188·1	141·9	0·01125	5·94
Aluminium[1] „ . .	„	„	58·4	44·0	0·02210	11·67

$$\text{Ratio of resistances, same length and area, } \frac{\text{aluminium}}{\text{copper}} = \frac{1 \cdot 96}{1}$$

$$\text{„ \quad „ \quad „ \quad weight, } \frac{\text{aluminium}}{\text{copper}} = \frac{0 \cdot 6}{1}.$$

3. Electrical tests of Aluminium-Bronze, compared with pure Copper wire.

—	Diameter.		Weight and Length.		Resistance and Length.	
	Millimetre.	Inch.	Lbs. per Mile.	Feet per lb.	Ohms per Mile.	Feet per Ohm.
Aluminium-bronze .	2·108	0·083	104	50·8	200·00	26·0
Pure copper . . .	„	„	110	48·0	7·91	667·3

$$\text{Ratio of resistances, same length and area, } \frac{\text{aluminium-bronze}}{\text{pure copper}} = \frac{25 \cdot 3}{1}.$$

This specimen of aluminium-bronze broke with a tensile stress of 70,000 lbs. per square inch, but several specimens had stood 100,000 lbs.

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[1] The results were obtained for an aluminium wire of cross area 0·008219 square inch, and reduced by calculation to the area of the copper wire, namely, 0·00709 square inch.—A. J.

Mr. W. H. Massey, would be glad if the Author could give some further explanation of the law which Sir William Thomson was said to have laid down with regard to wasted energy and interest on capital. At one of the British Association meetings, Sir William gave a rule for finding the size of copper conductor required for a certain purpose, and he directed attention to the fact that the most economical size of the copper conductor would be found by comparing the annual interest of the money value of the copper with the money value of the energy lost in it annually; but the Author stated that "the wasted energy must equal the interest on the capital expended in laying down the conductor to give the maximum useful economical result,"—which might or might not be true in every instance, as an example would prove if the cost of laying the conductor was small. **Mr. Massey.**

It had also been shown by Sir William Thomson that the size of conductor did not depend on the length of it through which current was to be sent; and, as every electric light engineer knew that twice the area of conductor would not carry twice the current (although twice the weight of copper would do so if put into two separate cables), it would appear that neither the length nor the size of a conductor should be considered apart from its shape, and that no law or rule could be called general which did not take into account the heat-radiating surface of the conductor and the character of the insulating material by which it was surrounded.

Dr. H. Militzer, of the Austrian Telegraph Administration, contributed some particulars of the conductors used in that department. From 1846 to 1855 a copper wire 2½ millimetres in diameter was employed almost exclusively. Trial of an iron 3-millimetre wire in 1852 gave unsatisfactory results because of its defective joints, and for a time no further effort was made in that direction. But as the number of conductors fixed to the poles increased, and crossings of the wire became more frequent, the exclusive use of copper was impracticable, on account of its insufficient tensile strength, and also because of its cost. Since 1856 iron had been almost exclusively used. The first iron wires had the same diameter—3 millimetres—and that size satisfied the conditions until about 1865, when high-speed and long-distance transmitters began to be adopted. Then by degrees 4½ and 5 millimetres were taken, and the latter dimension was now generally recognised as the standard for the whole network of Austrian telegraphs. At first efforts were made to reserve the use of the thicker wires for the long through lines, wires of 3 millimetres being retained for the local traffic. But experience showed that **Dr. Militzer.**

Dr. Militzer. the simultaneous employment of wires of different dimensions, hung to the same poles, was inconvenient; further, the smaller wires were not sufficiently resistant to the great cold of winter, and were found to break easily under the weight of the snow, which sometimes obstructed them to an almost incredible extent. Wire 3 millimetres in diameter had therefore only been retained in towns and in the immediate neighbourhood of large stations, where there was not room for big wires. It was, nevertheless, not improbable that its use would be discontinued even under these exceptional circumstances, recourse being had to silicium-bronze.

The iron wire used in Austria was not galvanized, but was steeped when hot in linseed-oil, which was expected to protect it from rust when in store. Some trials had been made of galvanized wire, but with only moderate success. The cost was enhanced nearly 30 per cent., while the valuable qualities inherent in the Styrian iron were injuriously affected by the process, since galvanized wire was much less easy to handle, and also became brittle. According to his experience, 3-millimetre iron wire ungalvanized would last for fifteen years, and similar wire 5 millimetres in diameter from twenty to twenty-five years, and that endurance was satisfactory. All the iron wire was made from Styrian and Carinthian ore, although some of the works were situated in Bohemia. The wire had to satisfy certain official conditions, which had remained almost unchanged for the last fifteen years, although the wire now furnished greatly surpassed the specifications alluded to. The administration insisted that 5-millimetre wire should bear, in a length of 16 centimetres, fifteen complete twists without cracking or breaking, and from fifteen to twenty bendings at right angles in opposite directions. It must also support a weight of 695 kilograms without breaking, even if it contained a joint. The wire was furnished in coils of 400 metres, with not more than three joints per coil. No special test for conductivity was exacted, because the Styrian iron, from its purity, was very constant in this respect. Joints were made by twisting each wire several times round the other and soldering the connection with tin, after having placed between the spirals a small length of copper wire as an additional security.

For spans, beyond from 250 to 300 metres, wire of cast steel or Bessemer metal was employed, ordinarily 3 millimetres in diameter. Trial had been made, for the neighbourhood of chemical works, of an American compound wire, but it had not answered, the iron core separating from the copper casing after a very short time.

Mr. Mosse.

Mr. J. R. **Mosse** observed that in thinly settled countries the strength of a telegraph wire was as important a consideration as its conductivity; for otherwise in forests the wire would be frequently broken by the falling of branches of trees, or by other casualties. Across the deep ravines in the "up country" of Ceylon, the spans of wire were sometimes as much as 600 yards, and for this distance strength was requisite. One point connected with the choice of a telegraph wire was not likely to occur to an electrician accustomed only to English practice, namely, what description of wire would be less generally useful for other than telegraphic purposes? About thirty years ago, a teamster in Nova Scotia who had broken his traces would occasionally climb the nearest telegraph post and cut off a few yards of wire to mend them, and then sometimes join the wire with a piece of string. Similarly telegraph wire was occasionally used for mending gaps in fences; but owing to stringent laws this practice has long since been discontinued. In North America the posts were generally of oak or juniper, spaced about 60 yards apart; including wire and a Morse instrument, say every 20 miles, the cost of a telegraph line several years ago was about £20 sterling per mile. The cost of transport in a new country necessitates the use of the lightest materials commensurate with strength. In Ceylon, about twenty years ago, many iron lattice bridges, 80 to 160 feet in length, 15 to 18 feet wide, manufactured in England, were carried several miles by coolies to the spot at which they had to be erected; and at the present day barrels of cement, bags of lime, and tools, were thus transported from the nearest point on the cart-road to the railway works, the load being generally slung on a pole and carried by two or four men. One coolie could carry about 50 lbs. a distance of some 10 miles per day, returning without a load to the starting point; and he would of course carry proportionately further when not so returning. Coolies with loads would not average more than 15 miles per day when on a long journey, and with wages at 10*d.* per day, the cost of transport by coolies was generally about 3*s.* 6*d.* per ton per mile, or say double the usual cost of transport by bullock carts.

Dr. Werner Siemens.

Dr. **Werner Siemens** thought the Author had with good reason drawn attention to the great importance of increasing the specific conductivity of the metals used for Electrical Conductors, as the working capacity of submarine or underground cables, under otherwise similar conditions, increased in direct proportion with the specific conductivity of the copper. In the Tables communicated by the Author, giving the specific conductivity of the copper

Dr. Werner Siemens. used since the time of the first cables, it was of great interest to observe to what a high degree industry was in a position to follow scientific demands, and how important it was to continue in the endeavour after still further improvements in this direction in the manufacture of copper. Considering that the value of the copper used in a submarine cable was only about one-twentieth part of the whole cost of the cable when laid, and that an improvement in the conductivity increased the working value of the cable in much greater ratio, it was worth while to use much dearer copper, if greater conductivity could be thereby obtained. The standard of conductivity still in use in England (pure copper) was no longer sufficient, since the limit of maximum conductivity was now approached. The conductivity of copper depended not alone on its chemical purity, but it was also influenced by the degree of softness. Moreover, the absorption of oxygen, hydrogen, and carbon, in so small quantities that they could not be detected by chemical tests, had a great influence on the conductivity of copper. These substances were taken up in the process of smelting, and in the necessarily repeated annealing during the drawing of the wire. Hence purity, as determined by chemical tests, was not a safe measure of conductivity. On these grounds he had proposed, as early as the year 1860, to take as the standard of conductivity that of pure mercury at a temperature of 0° Centigrade.[1] Taking the English standard, the maximum conductivity of copper was expressed by 58·9 in terms of the conductivity of mercury at the freezing-point; but this was certainly not the extreme limit of conductivity attainable. A copper wire, drawn without re-smelting from a piece of Caucasian reguline copper was found to have a conductivity of 61 according to the mercury standard. It was therefore probable that, by continuing the present efforts to obtain high conductivity, there would soon be in the market copper of greater conductivity than "pure copper." It would therefore be advisable that England should adopt the mercury standard accepted on the continent. He entirely agreed with the remarks on the great durability of iron wire for overhead conductors. Even ungalvanized iron wires had lasted unexpectedly long in neighbourhoods where the air was not much vitiated by manufactures. In Russia many conductors of ungalvanized iron wire, 5 millimetres thick, were still in existence which had been erected by Messrs. Siemens and Halske between 1854 and 1856. A firmly-adherent layer of oxide was soon formed on the surface of such wires, which

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[1] Poggendorff's Annalen, Bd. 110, § 1. Reprint of Papers, p. 229.

Dr. Werner Siemens.

completely protected the iron from further attacks of the oxygen of the air. The galvanization of wires usually adopted was a sufficient protection against ordinary impurities of the air even in thickly-populated and industrial neighbourhoods, but not in manufacturing or maritime districts. The Author regretted that steel wires had never been successfully cased with a protecting sheath of copper of good conductivity. It was therefore in such places absolutely necessary to use lead-covered steel wires or alloys of copper of considerable hardness—as for instance phosphor-bronze, which could withstand these destructive influences. That these wires had comparatively low conductivity was of small moment in overhead conductors, since the limit of working capacity of a telegraph circuit depended in large measure on its electrostatic capacity, which in the case of overhead conductors might be neglected in comparison with that of underground conductors. This circumstance was also in favour of the use of steel-wire conductors, in spite of their greater resistance, as in well-insulated overhead conductors the mechanical properties of the material were much more important than its conductivity. In so far as decrease in speed of working was concerned, this could be compensated for by using stronger batteries and correspondingly larger resistances in the instruments employed. For these reasons, since the time of the earliest of the more important projects which had been accomplished, overhead conductors had been made of iron, or later, of soft steel wire; while on the other hand, for all underground and submarine cables, copper wire of the highest attainable conductivity had been employed. He could not endorse the remark that the first cables insulated with gutta-percha were constructed with iron wires. The first telegraph lines with gutta percha insulation were those employed in Prussia between 1847 and 1850,[1] as he had mentioned on several occasions. Those underground lines contained copper wires 2½ millimetres in diameter covered by packing with solid gutta percha.

Mr. Weiller.

Mr. L. **Weiller** contributed the results of his experience in France on the improvement of electrical conductors. The first aerial conductor in that country was laid in 1848, between Paris and Rouen. It was of pure copper, and at the end of a few weeks stretched immoderately. At that time, France was in the midst of a revolution, and the great highways were patrolled by robbers rather

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[1] Poggendorff Annalen, Bd. 79, p. 481; Mémoire sur la Télégraphie Électrique, présenté à l'Académie des Sciences, le 15 avril, 1850; Reprint of Papers, pp. 33 and 51.

Mr. Weiller. than by the police. The Telegraph-Administration neglecting to remove the wire which lay on the Rouen road, the stretching having thrown down the telegraph-posts, thieves saved them the trouble. Mr. Bergon, the manager of the Post and Telegraphic administration in France, had told Mr. Weiller that at the end of eight days there remained not a yard of wire in the air. This, with other considerations, decided the authorities to use iron wire in future. Since 1848, the manufacture of iron had so improved that it was a matter of course that wire made of that material should also be better. Until very recently, the telegraph administration ignored the conductivity of their wires. They took at haphazard, as a standard, iron wire 4 millimetres (0·157 inch) in diameter, having an electrical resistance of 10 ohms per kilometre; but this resistance varied greatly with the quality of the wire. Only recently had they imposed a minimum resistance in the Government contracts, though it must be acknowledged they had obtained for iron-wire a quite sufficient conductivity in proportion to the price. Swedish wire best fulfilled the conditions of conductivity imposed; but its excessive weight, the continuous increase in the number of aerial wires, and the growing employment of multiple telegraphy, necessitated at present the employment of a wire at once lighter and of superior conductivity. For this reason, attention was now being had to the substitution for iron wire of steel, or of wires made of copper or its alloys.

The Author had sufficiently explained how they had been able to-day to produce commercially, copper wires having nearly twice the conductivity of those formerly used. The reduction of the sub-oxide, and the elimination of the metalloids always found in combination with copper, were the sole causes of their having attained for copper a conductivity nearly equal to that of silver. Also the electrical resistance attributed by Matthiessen to copper wire, still used as a standard, was no longer exact. This resistance was, when formulated, 20·57 ohms per kilometre, at 0° Centigrade for a wire 1 millimetre in diameter, while at present, for the same conditions, it was only 20 ohms per kilometer, and by recent progress in electrolysis, it had been further reduced to 19·56 ohms, or scarcely more than that of pure silver. These latest conductors possessed, therefore, from 5 to 6 per cent. greater conductivity than the older ones, which by easy calculation could be shown to be equivalent, in the case of an Atlantic cable, to two or three words more per minute than the capacity of the present conductors. This would be in the future a fruitful source of economy in cables connecting Europe with the antipodes.

Mr. Weiller.

From a mechanical point of view, however, the progress realised in copper wire, though very important, did not give sufficient results to warrant its employment aerially. Pure copper hardened little at the draw-plate by cold-drawing; it might be made to acquire sufficient mechanical strength, but its conductivity then lessened apparently, and it became rather more brittle. Furthermore, when it was quite pure, *i.e.*, contained merely traces of the sub-oxides, so slight that they could never be removed unless by substituting for them something else, it tended to expand or contract under the influence of heat or cold, and at the end of a few years to assume molecular deformation, which led to its deterioration or modified its electric qualities.

It was for this reason that attention had been paid to the removal from copper of its oxides, by means of phosphorus, and their replacement by small quantities of tin. This alloy, known as phosphor-bronze, had given, mechanically, wonderful results. By sacrificing its conductivity, a strength could be imparted to it equal to that of the best steel; but in that case there was no advantage in employing it in preference to steel or iron, which were much less costly. It was true that phosphor-bronze, like all its associates, resisted admirably the action of the weather which was not the case with iron or steel. Another advantage not to be despised in wire of phosphor-bronze was, that under its breaking-weight the molecular deformation acted by fibres, while in iron or steel wire it was granular. This fact to a certain extent accounted for the numerous failures of suspension-bridges made of iron wire which had ended by breaking under their own weight, although their sections were calculated for loads naturally much greater.

But if the qualities just attributed to phosphor-bronze made it of great value in purely mechanical applications, it was less so where electricity was concerned. It was known that phosphorus was an insulator rather than a conductor; also, that although this deoxidiser was only intended to act temporarily, traces of it always remained in the bronzes it deoxidised. Hence resulted either a great loss of conductivity, or, where only minute quantities of phosphorus were employed, a conductivity high but never homogeneous, by reason of the considerable variations imparted by traces of phosphorus to the conductivity of an alloy. This non-homogeneity of phosphor-bronze rendered the material unsuitable for telegraph lines. It was, therefore, necessary, as the Author had said, to look for a deoxidiser that was itself a conductor of electricity. Thus resulted the wires made of siliceous

Mr. Weiller. bronze. Such wire was now made in England, having a conductivity of from 97 to 99 per cent. of those of pure copper, possessing a tensile strength of from 28 to 29½ tons per square inch, and of extreme malleability. Such electrical and mechanical qualities were a powerful aid to the transformation of aerial lines, which became more and more necessary as their number increased, and as multiple-apparatus became improved.

The reduction of taxation had always been and would always be an important consideration to all governments, and the foregoing considerations indicated how this might be accomplished in respect of telegraph administration, by the employment of conductors capable of sending messages to double or treble the distance, while their capacity remained the same or even became increased. In this way it was not unreasonable to expect in the near future considerable reductions in international telegraph tariffs. There was another question, perhaps less generally important, but yet of considerable interest to the financial world, namely, the direct and easy communication between financial centres. Silicium-bronze would probably render a sure means of establishing such communication with a speed of transmission so high that exchange telegrams would always reach their destination in time to be useful.

It was not merely in aerial telegraphy, properly so called, that wires of high conductivity and great mechanical strength were called upon to render service. Their qualities rendered them eminently fitted to fulfil the special demands of military telegraphy. Every one knew with what scrupulous care were calculated to within a pound the weights, and to within a square inch the bulk, of the multitudinous impedimenta constituting the baggage of an army in the field. This precaution was indispensable, so as to shorten the string of vehicles which accompanied it, and constituted a great source of embarrassment to thos in command. The carriages used in field-telegraphy carried a number of reels wound with iron wire, generally 2 millimetre (0·079 inch) in diameter. If for this wire were substitute silicium-bronze wire of 1 millimetre in diameter, it would be practicable to reduce the weight to one-fourth, or to carry a lengt four times as great.

From another point of view, if, in the insulated wires als laid from these carriages, the present core, composed of ordinar copper-wire of scarcely any resistance to traction, were replace by one formed of strong silicium-bronze wire, the core itself woul possess the necessary strength, and it would become possible t reduce the thickness of the insulating medium, and consequently the space occupied on the reels. Mr. Weiller.

There had been essayed for submarine telegraphy the so-called light wires, less costly than the ordinary cables and allowing by reason of the diminution of bulk and weight, of the employment of laying-vessels of less size, or of a single vessel instead of several. Experiments had been made on a sufficiently large scale by the most eminent English engineers, especially by the late Sir William Siemens. The non-success of these trials was due to the inability of the hemp protection to withstand the strains of laying. Probably, if the necessary strength had been supplied by the core itself, and the covering been merely regarded as a protecting medium, success would have resulted.

For these reasons, Mr. L. Weiller was quite in agreement with the conclusions of the Author respecting conductors for aerial lines. But he differed from the opinion that for submarine cables the strength of the core was quite negligible. That was only so when the insulating coating had iron- or steel-wire protection; but how great would be the facility of laying and of transport, as well as the economy realised by the employment of a submarine cable, of which the conductor would at once transmit the current, and afford protection against mechanical strain.

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11 December, 1883.

JAMES BRUNLEES, F.R.S.E., President,
in the Chair.

The discussion upon the Paper "On Electrical Conductors," by Mr. Preece, occupied the whole of this meeting.

ANNUAL GENERAL MEETING.

18 December, 1883.

JAMES BRUNLEES, F.R.S.E., President, in the Chair.

The notice convening the meeting having been read,

Messrs. A. T. Atchison, R. W. P. Birch, T. H. Blakesley, G. Chatterton, F. S. Courtney, W. A. Dawson, J. M. Dobson, C. Frewer, H. S. Ridings, and T. M. Smith, were requested to act as Scrutineers for the election of the President, Vice-Presidents, and other Members of the Council for the ensuing year; and it was resolved that the Balloting lists should be sent to the Scrutineers for examination at intervals.

The Ballot having been declared open, the Secretary read the Annual Report of the Council upon the proceedings of the Institution during the year 1883, and upon its general condition.

The Telford Medals, the Telford and Manby Premiums, and the Miller Prizes, for 1883, and the Howard Quinquennial Prize for 1882, which had been awarded, were presented. (Pages 148 to 150.)

Moved, seconded, and after discussion Resolved,—That the Report of the Council be received and approved, and that it be printed in the "Minutes of Proceedings" in the usual manner.

Resolved,—That the best thanks of the Meeting be accorded to the Vice-Presidents and other Members of Council, for the time and trouble they have bestowed in promoting the objects of the Society.

Sir J. W. Bazalgette, C.B., Vice-President, returned thanks.

Resolved unanimously,—That the hearty thanks of the members be tendered to Mr. Brunlees, President, for the great attention he had paid to the duties of his office, and for the manner in which he had devoted himself to the interests of the Institution.

Mr. Brunlees, President, returned thanks.

Resolved,—That the members of the Institution desire to acknowledge their thorough appreciation of the value and importance of the Lectures on the "Practical Applications of Electricity," delivered in the past session, and the sense of their indebtedness to each of the Lecturers.

Mr. W. H. Preece, F.R.S., returned thanks.

Resolved,—That the thanks of the Institution be presented to Messrs. J. Clarke Hawkshaw and H. M. Brunel, the Auditors, for the careful manner in which they have examined and audited the accounts; and that Messrs. H. M. Brunel and Edward Bazalgette be requested to act as Auditors for the ensuing year.

A report from the Scrutineers was then read, stating that the following gentlemen had been duly elected:

President.

SIR JOSEPH W. BAZALGETTE, C.B.

Vice-Presidents.

Sir Frederick J. Bramwell, F.R.S.	George Barclay Bruce.
Edward Woods.	Sir John Coode.

Other Members of Council.

Benjamin Baker.	Harrison Hayter.
John Wolfe Barry.	William Pole, F.R.SS. L. & E.
George Berkley.	William Henry Preece, F.R.S.
Sir Henry Bessemer, F.R.S.	Sir Robert Rawlinson, C.B.
Edward Alfred Cowper.	Sir Edward James Reed, K.C.B., M.P., F.R.S.
Sir James Nicholas Douglass.	Sir W. Thomson, F.R.SS. L. & E.
Charles Douglas Fox.	Sir Jos. Whitworth, Bart., F.R.S.
Alfred Giles, M.P.	

Resolved,—That the thanks of the Meeting be given to Messrs. Atchison, Birch, Blakesley, Chatterton, Courtney, Dawson, Dobson, Frewer, Ridings, and Smith, the Scrutineers, for the important services they so readily undertook and have performed; and that the Ballot-Papers be destroyed.

Resolved,—That the thanks of the Members are especially due to Mr. Charles Manby, Honorary Secretary, to Mr. James Forrest, the Secretary, and to the other officers, for the way in which they have continued to conduct the business of the Institution.

Mr. Forrest returned thanks.

The meeting was then adjourned.

[REPORT OF THE COUNCIL.

REPORT OF THE COUNCIL FOR 1883.

Owing to the policy pursued by successive Councils, The Institution of Civil Engineers has become one of the most successful and prosperous of scientific societies, not only financially, but also in respect of the amount of professional knowledge diffused by its publications. Incorporated by Royal Charter to promote the Science and Practice of Civil Engineering, as defined or foreshadowed by Tredgold, who observed that "its scope and utility will be increased with every discovery in philosophy, and its resources with every invention in mechanical or chemical art,"[1] the details to be given in this report will show that the wide functions and the important purposes of the Institution have been well sustained during the past twelve months.

Constitution.

No change has been made in the Constitution since the By-Laws were altered five years ago. The alterations then made were mainly directed to a separation of the Associates into two groups, professional and non-professional. The Constitution is now sufficiently broad to include as Corporate Members all persons who, by training and experience, are entitled to be considered Civil Engineers, whatever branch of engineering they may follow. It is, however, well to repeat that, according to the By-Laws, no person can become a Corporate Member unless he has acquired eminence in the profession, or unless he has been trained as a Civil Engineer, and is, at the time of his application for admission, actually engaged in the design or the construction of engineering work. Candidates "who are not Civil Engineers by profession," are, however, eligible as Non-Corporate Associates; and the Council entertain the firm conviction that for the benefit of the Institution there should be such a class, selected from those who occupy a well-recognised position in connection with Science or the Arts. The Council take precautions, and exercise care by making inquiries respecting all candidates, so as to guard against the admission of unqualified persons, as also against erroneous classification. But they further rely on members refusing to sign any application unless they are personally acquainted with the

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[1] Minutes of Proceedings Inst. C.E., vol. xxvii., p. 181.

candidate and his career, believe him to come strictly within the By-laws and to be worthy of belonging to the Institution.

The Council desire to draw public attention to the fact that the use of the letters "C.E." is an assumption which is not founded on any qualification, and thus is one calculated to mislead. It should be the aim of all who hold the diploma of this Institution to discountenance such a custom, and always to adopt the official designations, or the abbrevations proper to their class, which are, for a Member:—"M. Inst. C.E."; for an Associate Member, "Assoc. M. Inst. C.E."; and for an Associate, "Assoc. Inst. C.E."

ROLL OF THE INSTITUTION.

The changes[1] that have occurred in the several classes composing the Institution, irrespective of the Students, have included the transfer of 40 Associate Members to the class of Members, and of 4 Associates to that of Associate Members; the election of 1 Honorary Member, 41 Members, 223 Associate Members, and 15 Associates; and the restoration to the register of 3 Associate Members. The deductions arising from deaths, resignations and erasures, have been 1 Honorary Member, 33 Members, 25 Associate Members, and 21 Associates. The net result, therefore, is an

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[1] During the last two Sessions the changes have been as shown in the following Table:—

—	Nov. 30, 1881, to Nov. 30, 1882.					Nov. 30, 1882, to Nov. 30, 1883.				
	Honorary Members.	Members.	Associate Members.	Associates.	Totals.	Honorary Members.	Members.	Associate Members.	Associates.	Totals.
Numbers at commencement	18	1,261	1,406	552	3,237	20	1,307	1,536	522	3,385
Transferred to Members	..	..	36	1		..	..	40	..	
Do. to Associate Members	..	..	..	10		..	..	..	4	
Elections	3	48	180	7	238	1	41	223	15	283
Restored to Register	..	..	..	..		..	..	3	..	
Deaths	1	29	13	11	−90	1	26	15	11	−80
Resignations	..	10	4	11		..	5	6	5	
Erased	..	..	7	4	148	..	2	4	5	203
Numbers at termination	20	1,307	1,536	522	3,385	20	1,355	1,701	512	3,588

increase of 48 Members, and of 165 Associate Members, with a decrease of 10 Associates, the Honorary Members remaining the same, Mr. Spottiswoode having died during the year of his election. The gross number on the books on the 30th of November was 3,588, as against 3,385 twelve months ago, being an increase of 203, or 6 per cent. in the year.

Among those lost by death are three old Members, Messrs. John Miller, James Gascoigne Lynde, and Joseph Mitchell. Mr. Mitchell, a pupil of Telford, was for some time "the father of the Institution." In its early days he reported the "Minutes of Conversations at the meetings," and, during his long connection with the Institution, lasting within a few months of sixty years, he ever took a warm interest in its advancement. The untimely death of Sir William Siemens must still be fresh in the minds of the members. It is some consolation to know, that his extraordinary merits have been generally recognised, and that, on the demand of the representatives of British science, he was accorded the distinguished honour of a public funeral service in Westminster Abbey.[1]

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[1] The full list of deceases is:—

Honorary Member:—William Spottiswoode, M.A., LL.D., Pres. R.S.

Members:—Robert Bruce Bell; Valentine Browne; Robert Reginald Burnett; John Octavius Butler; Edmund Small Cathels; William Richard Cole; Robert Daglish; Alexander Drysdale; Charles Greaves; John Edward Hartley; Jabez James; Edward John Jones; James Gascoigne Lynde; James Edward McConnell; John Miller, F.R.S.E.; Joseph Mitchell, F.R.S.E.; Theophilus Nicholls; John Paton; Thomas William Rumble, F.R.S.E.; Sir Charles William Siemens, D.C.L., F.R.S., *Member of Council*; William George Smart, M.A.; Thomas Samuel Speck; John Francis Ure; Cromwell Fleetwood Varley, F.R.S.; Henry Frederick Whyte, B.A.; and Thomas Robert Winder.

Associate Members: Charles Christian Claudius Albeck; Richard Francis Alford; William Beattie; William John Boys; Edward Hedley; Samuel Furness Holmes; Arnold Horne; Louis Auguste de Jacques de Labastide; Arthur Hemery Le Breton; Octavio Olavegoya; Henry Blackburne Parry; Edward Ellison Prichard; Walter Scott; Henry Augustus Severn; and Douglas D'Arcy Wilberforce Veitch.

Associates: Henry Lee Corlett; Lewis Cubitt; Ralph Firbank; Henry Grissell; General Sir Henry Drury Harness, K.C.B., R.E.; Henry Harrison; Lieut.-Colonel John Rawdon Oldfield, R.E.; Major-Gen. Henry Young Darracott Scott, C.B., R.E., F.R.S.; James Shaw; William Watson, M.A.; and George Wythes.

The resignations of the following members have been accepted:—

Members: Adam Fettiplace Blandy; Henry Byrne; Charles Jopp; John McLandsborough; and William Mason.

Associate-Members: David Cowan; George William Goodison; Stephen Lancelot Koe; Henry Clements Perram; Robert Pitt; and William Wright.

Associates: James Lloyd Ashbury; Frederick Ebenezer Baines; Major Archibald Cuthbert Bigg-Wither; Joseph Bray; and Charles Goolden, M.A.

ADMISSION OF STUDENTS.

In view of the large number of applicants for admission, and in order to discountenance those who merely desire to acquire the substantial privileges of this class without intending, or being competent, to follow engineering as a profession, the Council have of late years required candidates to furnish some account of their scholastic career, and generally to afford information as to their fitness. This it is hoped has been to a certain extent successful. There are now, in different parts of the kingdom, so many colleges and public educational bodies giving special instruction in those sciences on which a successful practice of engineering depends, and the facilities for attending these are so much greater than when the Student Class was established, that a certificate of some recognised engineering school may soon be expected. The Council appeal to the Corporate Members (who alone possess the right to nominate Students) to recommend only such persons as are, in the words of the rules, "*bonâ fide* in the course of preparation and training" under the proposer "with the object of following the profession of a Civil Engineer." During the Session 81 Students were elected Associate Members, and 175 candidates were admitted. The total number of Students now on the books is 722 as against 707 at the corresponding period last year.

ELECTION OF COUNCIL.

With respect to the constitution of the Council, a memorial, dated 9th April, 1883, was received from some of the leading Members of the Institution practising in India, the most important point of which memorial was to ask the Council to convene a Special General Meeting of Corporate Members for considering, and, if approved, of enacting, a new By-law to enable Members resident in India to return one Member to the Council, and to effect the election by a use of voting papers. The Council remitted this memorial to Messrs. Radcliffes, Cator, and Martineau, Solicitors, for their opinion. This was given in unequivocal terms, namely, that any such By-law would, under the existing Charter, be "absolutely null and void;" that a supplemental Charter would have to be obtained to render such a By-law legal; that such supplemental Charter could only be obtained by petition to the Crown; and that the law officers of the Crown would not be likely to recommend the grant of such supplemental Charter unless the Corporate Members were almost unanimously in favour of the proposed change. The Council, in their reply to the memorialists, while agreeing that arguments might possibly be adduced in favour of an election of the whole Council by means of voting papers, stated that no satisfactory arguments could be advanced in favour of this being done by one section of the Members, and that they were therefore not prepared to memorialize the Crown for a supplemental Charter embracing such a provision.

In connection with this memorial, the Council take this opportunity of recording the principles by which they are guided in preparing the balloting list for the election of Council. They seek to make it representative of every branch of engineering, and they are also not unmindful of the desirability of representing, as far as possible, different provincial districts which are important centres of engineering practice. But the paramount object is to choose those engineers who, while their names and professional standing will give dignity to the Institution, are most likely to be useful in the administration of its affairs. The Council is the governing body of a great and influential Corporation, whose interests require constant vigilance, and frequent meetings both of the Council and of Committees. Although there may be cogent reasons for returning some members who, from various causes, cannot always give close personal attention to its business, yet it is a necessity, that the majority of the Council should be easily accessible.

In preparing the balloting list for the election of a Council this evening, four vacancies occurred under "other Members of Council," arising from the nomination of Sir John Coode as a Vice-President, the death of Sir William Siemens, and the retirement of Mr. A. M. Rendel and of Mr. David Stevenson. Bearing the foregoing principles in mind, the Council have added to last year's list the names of gentlemen connected with metallurgy, mining, dock- and harbour-works, town-sewerage and water-supply, and naval architecture.

CONTRIBUTIONS TO THE FUNDS.

It may be interesting to note that the large income now received is simply the result of growth in numbers, and is not due to an increase in the subscriptions, which remain the same as in 1837, when the present scale was adopted, while the material advantages offered have in the interval increased tenfold.

At the time referred to it was decided to regard those persons who resided within ten miles of the General Post Office as resident, and those beyond such limits as non-resident, and the rates of annual subscriptions were fixed at four guineas and three guineas respectively for Members, and at three guineas and two and a half guineas for Associates; and the same principle has since governed the scale for Students, which is two guineas and one guinea and a half. This rule was no doubt sound enough when originally framed in the pre-railway days, but it is questionable whether it would not now be more in accordance with justice to regard all persons as resident who remain within the United Kingdom, restricting the title of non-resident to those beyond the sea.

This is the fifth year since the accounts have been so set forth as to show at a glance, on the debit side, the three items of Income Proper, Capital, and Trust Funds; while on the credit side have also been given under three heads, the General Expenditure, Capital Investments, and Trust Fund Disbursements. At the first-named period these totals amounted to £14,229 17*s.* 8*d.* for receipts, and £14,450 10*s.* 6*d.* for expenditure; this year they are £17,578 13*s.* 11*d.* and £17,431 13*s.* 7*d.* respectively. The excess of income proper for the year 1883 over 1882 amounts to about 5¼ per cent. The figures for this year will be found, in detail, in the certified Abstract of Receipts and Expenditure attached to this report.

Collection of Subscriptions.

The By-laws instruct the Council that no person can remain on the books whose subscription has been unpaid for two years. In some few cases where it has been ascertained that "from ill-health, advanced age, or other sufficient cause," a Corporate Member has failed to carry on a lucrative practice, and where the application of the By-law would have been harsh, the Council have exercised the discretionary power given them by remitting the arrears. No subscription is now due for 1882, while the amount outstanding for 1883 is only £479 6*s.*, or a little more than 4 per cent. of the receipts under this head.

Sessions and Meetings.

For some years past gradual changes, with the object of economising time, have been made in the mode of conducting the business at the meetings. Formerly, at the commencement of a meeting, an abstract of the proceedings at the previous one was read, presents were announced, and the proposal papers of candidates for election were given at great length. These several formalities occupied about one-third of the duration of the meeting. At present the minutes are speedily got through, and the only other preliminary is the introduction of new members, after signing the register.

Last Session there were twenty-four Ordinary Meetings, at which sixteen Papers were read and discussed, the President's Inaugural Address occupying one evening.

A feature in the "Minutes of Proceedings," which has not perhaps attracted general attention, is the wide geographical range of the countries whose engineering has been dealt with, either in the communications read and discussed, in the Selected Papers, or in the Abstracts from foreign sources. There is no civilised country, from Japan in the far east to California in the far west, from New Zealand to Norway, the Public Works of which have not been referred to; and in several cases—as for instance the Paper on the mineral resources of Tonking—information has been given which, in addition to its professional importance, was of great general interest. In the same way, matters of moment to all classes of engineers, to naval architects, and to the great manufacturing industries of the country, are contained in the volumes; while several of the communications prove that the reproach hitherto levelled against English engineers, of neglecting theory, is no longer true. The Foreign Abstracts have indicated the progress of engineering science abroad, thus inciting the members to record the results of their original researches; and it is a pleasure to note that original contributions have been received from several eminent foreign engineers.

In order to show the diversity of subjects brought under consideration, a brief reference to the Papers read at the meetings, or printed in the Proceedings may be interesting. The first, by Major Allan Cunningham, R.E. (who subsequently was elected an Associate), gave the results of a series of important hydraulic experiments. The next Paper, read, unfortunately, after the death of its accomplished Author, Mr. Robert Briggs, was on the American practice in Warming Buildings by Steam, and described a system which, though only used to a limited extent in Europe, has become general in the United States. Following this came the account by Mr. Daglish of the sinking of two shafts at the Marsden Colliery, referring to a department of the profession, which is one of the most ancient, interesting, and, in this country at least, important of all, as demanding both scientific and professional knowledge of a high order. These three Papers, together with the reports of the oral discussions and the correspondence to which they gave rise, and the Report of the Annual General Meeting, furnished about one-half the material for the first volume of "Minutes of Proceedings" for the Session of 1882–83, which also contained nine Selected Papers, several Obituary Notices, and Foreign Abstracts. The second volume comprised, as Minutes of Proceedings proper, *i.e.* reports of the meetings, the Presidential Address of Mr. Brunlees, and Papers by Mr. William Anderson, on "The Antwerp Waterworks;" by Mr. John Fernie, "On Mild Steel for Locomotive Fireboxes;" and by Messrs. Lightfoot and Thompson on "Repairing-Slipways for Ships." In the third volume appeared Mr. William Morris's account of "Covered Service-Reservoirs," a concise and interesting repertory of information concerning works of this nature in England and on the Continent; Mr. Tweddell's valuable communication "On Hydraulic Machine-Tools," with which the Author's name is so closely associated, and Papers by Mr. A. McDonnell "On Stamping under the Steam-Hammer;" by Mr. William Smith "On the Summit-level Tunnel of the Blaenau-Festiniog Railway;" and by Mr. P. O'Meara "On Irrigation in New Countries," being mainly a description of the system pursued in Colorado. The fourth volume contained Mr. J. Mackenzie's memoir "Resistance on Railway Curves," an ingenious speculation as to the causes of some instances of derailment; while Mr. J. N. Paxman, who broke new ground in his account of the "Kimberley Diamond Fields," clearly showed how dependent all modern enterprises are upon the skill and judgment of the Civil Engineer. The concluding Meetings of the Session were devoted to the reading and discussion of Papers by Messrs. Alexander Leslie, John George Gamble, and John Addy, on the Waterworks of Edinburgh, of Port Elizabeth, South Africa, and of Peterborough, respectively.

The Selected Papers included in Section II. of the Proceedings may be of equal merit with those read and discussed, and, as in the case of Mr. Darwin's memoir "On the Thrust of Sand," may receive acknowledgments of equal value and distinction. The mention of this will perhaps allay the disappointment occasionally felt by an Author, on learning that his Paper has been accepted for printing, but not for being publicly read with a view to discussion.

The Council have had much satisfaction in awarding to the Authors of some of these communications:—Telford Medals and Premiums to Messrs. R. H. Tweddell, G. H. Darwin, W. Anderson, Major A. J. C. Cunningham, R.E., and A. Leslie; Telford Premiums to Messrs. J. G. Gamble, P. O'Meara, W. Morris, J. Fernie, J. Daglish, Prof. Dr. J. Weyrauch, T. C. Fidler, C. H. Moberly, J. Standfield, W. C. Unwin, J. Harding, and C. F. Tufnell; and the Manby Premium to Messrs. T. B. Lightfoot and J. Thompson. The details of these awards will be found in the Appendix to this Report.

In the nine years which have elapsed since the first publication of the Foreign Abstracts, the number of Journals and Transactions of Societies laid under contribution has been doubled, making the work of selection more difficult; but the experience gained by the abstractors, and the fact that certain established periodicals of high repute continue to obtain most of the best articles, render this work less laborious than it would otherwise be. The Council appeal to engineers abroad to send, as an important aid to this work, private copies of Papers contributed by them to foreign or colonial societies.

The subjects treated at the special meetings of Students were of a fairly varied character. Eight meetings were held, in March, April, and May. Of the nine Papers then read and discussed, one by Mr. H. J. Eunson, "On a deep Boring at Northampton," and another by Mr. P. V. Appleby, "On Iron and Steel in tension, compression, bending, torsion, and shear," have been printed in the 'Minutes of Proceedings' (Vol. lxxiv. pp. 270 and 258). Miller Prizes have been awarded to the Authors of these Papers, as well as to Mr. A. Beckwith, to Mr. T. S. Lacey, and to Mr. H. H. Parkinson. The Council regret that no Paper has been received of sufficient importance to warrant the award of a Miller Scholarship.

DATE OF ANNUAL MEETING.

The Council have had under consideration a memorial from several non-resident Members, urging that the date of the Annual General Meeting as fixed by the By-laws, viz., the Tuesday previous to Christmas-Eve, is very inconvenient, especially when the Tuesday is closely followed by Christmas-Eve, as it will be in 1884. The memorialists state that they have no desire to suggest an alteration of date merely to suit their own convenience; but they are led to believe that if the meeting were held at the end of the Session, viz. in May, it would enable many more country members to attend, and might at the same time be equally desirable in other respects.

The Council have, on several occasions, carefully discussed the whole question, with every desire to meet the views of the memorialists, but have felt compelled to arrive at the conclusion, that the balance of advantages is in favour of the present practice.

HOWARD QUINQUENNIAL PRIZE.

It affords satisfaction to the Council to record that, previous to the death of Sir William Siemens, it had been unanimously decided to award to him the Howard Quinquennial Prize for 1882, in consideration of his important discoveries, and of the valuable improvements he had effected, in the manufacture of Iron and Steel. There is a melancholy interest attaching to the notification of this award, as its acknowledgment by Sir William was one of the last acts of their much-regretted colleague.

LECTURES.

As far back as 1868 it was suggested that a new departure might be made with advantage to young engineers by the establishment of Readerships. The idea was, however, not carried out, and the establishment of Supplemental Meetings for Students was thought to be a more satisfactory provision. The Council then undertook to institute an inquiry into the state of engineering education at home and abroad, and this led to the issue of a volume containing much information on the subject.

In August, 1879, the expediency of instituting, in addition to the Ordinary Meetings, Lectures on special subjects of engineering was mooted. It was felt that if a limited number of lectures could be arranged, to be delivered by men of eminence, not on the elementary subjects of the class-room, but on the principles involved in the action of "the Great Sources of Power in Nature," and their practical applications, such a course would meet the provisions of Section xiii. of the By-laws in an appropriate manner. In March, 1882, the Council resolved to give effect to this idea, and settled the arrangements for a first series of lectures for the Session 1881–82, but it was then too far advanced to admit of their delivery. The matter was consequently postponed till this year, when six lectures were delivered by as many lecturers "On the Practical Applications of Electricity." These were given on Thursdays fortnightly, between February 15th and May 3rd. The lectures were as under: —"The Progress of Telegraphy," by Mr. W. H. Preece; "Telephones," by Sir Frederick Bramwell; "The Electrical Transmission and Storage of Power," by the late Sir William Siemens; "Some Points in Electric Lighting," by Dr. John Hopkinson; "Electricity applied to Explosive Purposes," by Sir Frederick Abel; and on "Electrical Units of Measurement," by Sir William Thomson.

It may be remarked that all the Lecturers belonged to the Institution and to the Royal Society, and that their services and those of their assistants were in every case given gratuitously. The disbursements under the head of Electrical Lectures, in the annexed statement of accounts, were strictly incurred in making the necessary arrangements within the Institution.

The Council feel assured that the members will fully appreciate the amount of time and labour required in the preparation of such lectures, which were highly successful, and attracted crowded audiences, so much so indeed that many persons who wished to be present were excluded for want of accommodation. It may be observed that, according to the By-laws, each Corporate Member is entitled to introduce one friend to every Ordinary Meeting. The Council therefore thought they would not be justified in withholding this privilege for the special meetings.

The Council have arranged for a second course of six lectures this Session, the subject being "Heat in its Mechanical Applications." Two have already been delivered, one "On the General Theory of Thermodynamics," by Professor Osborne Reynolds; the other on "The Generation of Steam, and the Thermodynamic Problems involved," by Mr. W. Anderson.

It is intended that these discourses on Electricity and on Heat shall be printed, and issued to the members.

OTHER SOCIETIES.

For many years the free use of the rooms has been granted for the meetings of other Societies dealing with branches of Engineering. The Meteorological was the first Society to whom permission was given, on the 24th of November, 1857, at the instance of the late Mr. Robert Stephenson, then the President of this Institution, and who occupied at the same time the Chair of the Meteorological Society. The Telegraph Engineers have met here on the second and fourth Thursdays of the month ever since their foundation on the 28th of February, 1872. Other Societies which have availed themselves of this privilege in the past twelve months, were the Mechanical Engineers, who assembled for the first time in this room on the 1st of May, 1873; the Iron and Steel Institute, who commenced meeting in this hall on the 6th of May, 1874, the Gas Institute, and the Society of Chemical Industry. By the courtesy of the respective Societies, all the members of the Institution of Civil Engineers are invited to attend their meetings.

TELFORD AND MILLER TRUST-FUNDS.

With a view to the simplification of the accounts of the Telford and Miller Trust-Funds, the Council have sold £435 9*s.* 2*d.* Consols, and purchased a like amount in Annuities. By this operation the Telford Bequest, standing in the books last year in two stocks—viz., £2,839 10*s.* 10*d.* Consols, and £2,586 0*s.* 11*d.* Reduced, is now represented by £5,425 11*s.* 9*d.* Consols, and the Unexpended Dividends by £3,290 13*s.* Reduced, in place of £2,377 10*s.* 5*d.* Consols, and £913 2*s.* 7*d.* Reduced. Similarly, the Unexpended Dividends of the Miller Fund now stand in £1,999 14*s.* 7*d.* Reduced, instead of £643 19*s.* 8*d.* Consols, and £1,355 14*s.* 11*d.* Reduced. The capital of this Trust was always placed in one security. With regard to the items "Unexpended Dividends," it may be explained that for many years prior to 1861, and subsequently for a short period, the interest on these Trust-Funds was not all appropriated. In 1861 an account was made out, since continued, and then and afterwards the balances due to the Trusts were invested. Of late years the Council have distributed, in terms of the Bequests, the interest on the original Funds *plus* the interest on the accumulations. Those of the Miller Fund arose mainly before the establishment of the Student class in 1867, the terms of Mr. Miller's Will limiting the benefits of the Fund to "Students of the Institution."

THE PROPERTY OF THE INSTITUTION.

The invested funds now amount to £43,250, and the trusts to £14,642 13*s.* 10*d.*, together £57,892 13*s.* 10*d.* A bequest of £50, less legacy duty, has been received from the executors of Mr. William Beattie, Assoc. M. Inst. C.E. Previous bequests, which were not left in trust, and do not therefore appear in the accounts, ought to be remembered and acknowledged, although some of the amounts were absorbed in the rebuilding of these premises in 1868. These were:—

Robert Stephenson bequest .	£2,000
Miller bequest	£2,000
Errington bequest	£1,000
Locke bequest	£1,000
Appold bequests	£1,800
Napier bequest	£100

Of the invested funds, £16,892 13*s.* 10*d.* are in Government 3 per cents., and the remainder in 4 per cent. Debenture Stocks of the leading British railway companies. The other property of the Institution consists of the lease of the premises, the Library, the stock in hand of the Minutes of Proceedings and of pamphlet editions of many of the Papers, the portraits of Past-Presidents, original drawings, pictures, and furniture. The premises are insured in the Guardian Fire Office for £12,000, and the other effects in the Sun Fire Office for £20,000.

The Charter and stock certificates are deposited with Messrs. Coutts & Co., the bankers, whose senior partner, Mr. H. L. Antrobus, is the Treasurer of the Institution. Dividends of every description are paid direct to the bankers, and the Auditors have been furnished with certificates from the recognised officers of the various companies, that the list of securities given in the abstract of accounts is correct.

THE LIBRARY.

Those who recollect the room in which, about fifteen years ago, former Presidents of the Institution used to receive their guests at the annual Conversazioni, and who compare it with the present Library, which, spacious as it is, has not proper accommodation for all the books, must acknowledge that the collection has kept pace with the growth of the Institution. The Library contains about 19,000 volumes, has a yearly increase of about 800 volumes, and may fairly be regarded as the best existing reference-library on engineering science. As, for the most part, only those works are placed on the shelves which bear directly or indirectly on subjects of professional interest, the volumes are more accessible than in some larger libraries. The merits of the Library are, perhaps, not sufficiently known to be duly appreciated; but to the practical engineer, as well as to the inquiring student, it offers an abundance of valuable information which cannot be obtained elsewhere. The subject-index enables a reference to be made to any special branch of engineering, and the classified arrangement on the shelves indicates what books have been published on each subject. There are also collected in numerous volumes of "Tracts," a large number of reports, and other miscellaneous documents, which are of particular value, as many are either unpublished or are out of print. In this department, however, the assistance of engineers who have works abroad, or in the colonies, is urgently needed, as much valuable printed matter relating to such works cannot be secured except by presentation from the engineers who draw up the reports, or from residents in foreign parts, and many serious gaps consequently exist. The co-operation of members of all classes, both at home and abroad, is therefore earnestly desired in order that the Library may contain a complete record of engineering literature, and may continue in the future the rate of progress that has hitherto prevailed.

THE NORTHERN PACIFIC RAILROAD.

During the recess a letter was received from the Foreign Office, enquiring whether the Institution would wish to be represented at the opening of the Northern Pacific Railroad, and if so, offering to place at its disposal one of the six sets of invitation-papers which had been forwarded to the Secretary of State by the President of the Railroad Company. The President, Mr. Brunlees, being unable to accept the invitation, by reason of previous engagements, and having ascertained that Sir Joseph Bazalgette and Mr. Woods, Vice-Presidents, were absent at the time, and thinking that Sir Frederick Bramwell, Vice-President, would not wish so soon to repeat his visit to the United States, persuaded Mr. Bruce, the junior Vice-President, to act as the representative of the Institution. It will be within the recollection of the members that the first meeting of the present Session was wholly occupied by Mr. Bruce's vivid account of his experiences and of the reception he met with during his visit. The following is extracted from the Minutes of the Ordinary Meetings:—

"On the motion of the President a vote of thanks was passed to Mr. Bruce by acclamation, alike for the narrative he has given, and for devoting so much of his time, and undertaking so long a journey, for the interests of this Institution."

CONCLUSION.

The Council think that whether regard be had to the primary object of the Institution, the advancement of the Science of Civil Engineering, or whether it be had to the growth of the Institution and to that of its Funds, they may be looked upon as having faithfully discharged the trust confided to their care by this Corporation.

[RECEIPTS AND EXPENDITURE.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£.	s.	d.	£.	s.	d.
To balance in the hands of the Treasurer	947	0	9			
" " Secretary	16	4	10			
				963	5	7

INCOME.

	£.	s.	d.	£.	s.	d.
— Subscriptions:—						
Arrears	383	5	0			
Current	11,022	18	0			
Advance	62	7	6			
— Library-Fund	209	14	0			
— Minutes of Proceedings:—Repayment for Binding, &c.	183	14	3			
— Publication-Fund	5	9	6			
— Interest on Deposit-Account	55	6	3			
— Miscellaneous Receipts	24	5	0			
				11,946	19	6

— Dividends: 1 year on

£.	s.	d.	*Institution Investments.*	£.	s.	d.	£.	s.	d.
4,750	0	0	Great Eastern Railway 4 % Debenture Stock	184	17	2			
6,000	0	0	London and No. Western Ditto	233	10	0			
1,500	0	0	London, Brighton, S. C. Do. .	58	7	7			
3,000	0	0	North Eastern Ditto . . .	116	15	0			
3,000	0	0	Great Northern Ditto . . .	116	15	0			
3,000	0	0	Lancashire and Yorks. Ditto .	116	15	0			
3,000	0	0	Great Western Ditto . . .	116	15	0			
3,000	0	0	Caledonian Ditto	117	4	1			
3,000	0	0	Midland Ditto	116	15	0			
3,000	0	0	Highland Ditto	117	4	2			
1,500	0	0	London, Brighton, and S. C. Ry. 4½ % Ditto	65	13	4			
3,000	0	0	Manchester, Sheffield, and Lincolnshire Ditto	131	6	10			
2,088	11	8	New Three per Cents. . . .	61	3	2			
411	8	4	Ditto (New purchase) . . .	–	–	–			
			6 months on						
3,000	0	0	Great Western Ry. 4% Debenture Stock (New purchase)	58	11	3	1,611	12	7
£43,250	0	0	Total nominal or par value.						

Carried forward . . . . . . £14,521 17 8 *from the* 1st DEC., 1882, *to the* 30th NOV., 1883.

PAYMENTS.

Cr.

General Expenditure.

	£.	s.	d.	£.	s.	d.
By House and Establishment Charges:—						
Repairs, General	123	2	11			
Decoration of Premises	535	0	0			
Rent	640	19	3			
Rates and Taxes	383	1	10			
Rent of Telephone Line and Instruments	23	13	0			
Insurance	41	16	6			
Fixtures and Furniture	815	14	9			
Lighting and Warming	108	19	5			
Tea, Coffee, &c.	58	14	7			
Assistance at Meetings	28	7	0			
Household Expenses	146	2	10			
				2,905	12	1
— Postages, Telegrams, and Parcels	183	1	9			
— Stationery and Printing	608	12	9			
— Watt Medals	9	10	0			
— George Stephenson Medal	2	7	6			
— Diplomas	55	14	10			
— Annual Dinner (Official Invitations, &c.)	216	18	11			
				1,076	5	9
— Salaries	1,900	0	0			
— Clerks, Messengers, and Housekeeper	734	14	4			
— Donation to late Housekeeper	30	0	0			
				2,664	14	4
— Library:—						
Books	295	1	5			
Periodicals	38	16	8			
Binding	47	19	11			
				381	18	0
— Publication:—						
"Minutes of Proceedings" (Vols. lxxi., lxxii., lxxiii., and lxxiv.)				5,768	6	8
— Cost of Transfer of Stock				2	4	2
— Electrical Lectures				304	15	0
Carried forward				£13,103	16	0

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*continued.*

Dr.

	£.	s.	d.	£.	s.	d.
Brought forward				14,521	17	8
Capital.						
To Legacy of the late W. Beattie	49	2	9			
— Admission-Fees	3,063	18	0			
— Life Compositions	469	17	6			
				3,582	18	3

Trust Funds.

To Dividends:—

£.	s.	d.		£.	s.	d.	£.	s.	d.
			Telford Fund.						
			6 months on						
2,839	10	10	Three per Cent. Consols	41	3	6			
2,377	10	5	Three per Cent. Consols (Unexpended Dividends)	34	9	6			
5,425	11	9	Three per Cent. Consols	79	13	10			
			1 year on						
3,290	13	0	Three per Cent. Reduced (Unexpended Dividends)	96	7	4			
							251	14	2
8,716	4	9	Total nominal or par value.						
			Manby Donation.						
			1 year on						
250	0	0	Great Eastern Railway Four per Cent. Debenture Stock				9	14	7
			Miller Fund.						
			6 months on						
643	19	8	Three per Cent. Consols (Unexpended Dividends)	9	6	8			
			1 year on						
3,125	0	0	New Three per Cents.	91	10	0			
1,999	14	7	Three per Cent. Reduced (Unexpended Dividends)	58	10	11			
							159	7	7
5,124	14	7	Total nominal or par value.						
			Howard Bequest.						
551	14	6	New Three per Cents.				16	3	2
							£18,541	15	5

Summary of Investments.

	£.	s.	d.	£.	s.	d.
Institution Investments				43,250	0	0
Trust Funds—						
Telford Fund	8,716	4	9			
Manby Donation	250	0	0			
Miller Fund	5,124	14	7			
Howard Bequest	551	14	6			
				14,642	13	10
				£57,892	13	10

from the 1st DEC., 1882, *to the* 30th NOV., 1883.

PAYMENTS—*continued.*

Cr. £.	s.	d.		£.	s.	d.	£.	s.	d.
			Brought forward				13,103	16	0
			CAPITAL-INVESTMENTS.						
By 3,000	0	0	Great Western Ry. Four per Cent. Debenture Stock	3,453	13	3			
— 411	8	4	New Three per Cents.	413	19	9	3,867	13	0
£3,411	8	4							
							16,971	9	0
			TRUST-FUNDS.						
			By Telford Premiums	287	12	10			
			— Miller Scholarships	80	0	0			
			— Miller Prizes	73	1	3			
			— Manby Premium	19	10	6	460	4	7
							17,431	13	7
			— Balance, Nov. 30, 1883, viz.:—						
			Cash in the hands of the Treasurer	1,083	15	5			
			„ „ Secretary	26	6	5	1,110	1	10
							£18,541	15	5

Examined with the Books and found correct.

(Signed) J. CLARKE HAWKSHAW } *Auditors.*
H. M. BRUNEL

JAMES FORREST, *Secretary,*
5th December, 1883.

PREMIUMS AWARDED.

SESSION 1882–83.

THE COUNCIL of The Institution of Civil Engineers have awarded the following Premiums:

FOR PAPERS READ AT THE ORDINARY MEETINGS.

1. A Telford Medal and a Telford Premium to Ralph Hart Tweddell, M. Inst. C.E., for his Paper "On Machine-Tools, and other Labour-Saving Appliances, worked by Hydraulic Pressure."
2. A Telford Medal and a Telford Premium to William Anderson,[1] M. Inst. C.E., for his Paper on "The Antwerp Waterworks."
3. A Telford Medal and a Telford Premium to Major Allan Joseph Champneys Cunningham, R.E., Assoc. Inst. C.E., for his Paper on "Recent Hydraulic Experiments."
4. A Telford Medal and a Telford Premium to Alexander Leslie, M. Inst. C.E. for his Paper on "The Edinburgh Waterworks."
5. A Telford Premium to John George Gamble,[2] M.A., M. Inst. C.E., for his Paper on "The Waterworks of Port Elizabeth, South Africa."
6. A Telford Premium to Patrick O'Meara, M. Inst. C.E., for his Paper on "The Introduction of Irrigation into New Countries, as illustrated in North-Eastern Colorado."
7. A Telford Premium to William Morris, M. Inst. C.E. (of Deptford), for his Paper on "Covered Service-Reservoirs."
8. A Telford Premium to John Fernie,[3] M. Inst. C.E., for his Paper on "Mild Steel for the Fireboxes of Locomotive Engines in the U.S.A."

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[1] Has previously received a Watt medal and Telford premiums.

[2] Has previously received a Telford premium.

[3] Has previously received a Watt medal and the Manby premium.

9. A Telford Premium to John Daglish, M. Inst. C.E., for his Paper on "The Sinking of two Shafts at Marsden, for the Whitburn Coal Company."

10. The Manby Premium to Thomas Bell Lightfoot, M. Inst. C.E., and John Thompson, for their Paper on "The Design and Construction of Repairing Slipways for Ships."

FOR PAPERS PRINTED IN THE PROCEEDINGS WITHOUT BEING DISCUSSED.

1. A Telford Medal and a Telford Premium to George Howard Darwin, M.A., F.R.S., for his Paper "On the Horizontal Thrust of a Mass of Sand."

2. A Telford Premium to Professor Dr. James Weyrauch,[1] for his Paper on "Various Methods of Determining the Dimensions of Iron Structures."

3. A Telford Premium to Thomas Claxton Fidler, M. Inst. C.E., for his Paper on "A Graphic Solution of the Strains in the Continuous Girder, with some Remarks on Continuous-Girder Bridges."

4. A Telford Premium to Charles Henry Moberly,[2] M. Inst. C.E., for his "Account of some Further Tests of Riveted Joints of Steel Plates for Boiler-Work."

5. A Telford Premium to John Standfield, M. Inst. C.E.., for his Paper on "The Raising of the SS. 'Austral.'"

6. A Telford Premium to William Cawthorne Unwin,[3] B.Sc., M. Inst. C.E., for his Paper on "Current-Meter Observations in the Thames."

7. A Telford Premium to Josiah Harding, M. Inst. C.E., for his Paper on "Apparatus for Solar Distillation."

8. A Telford Premium to Carleton Fowell Tufnell, Assoc. M. Inst. C.E., for his Paper on "Economical River-Training in India."

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[1] Has previously received a Telford medal and a Telford premium.
[2] Has previously received a Telford premium.
[3] Has previously received a Telford medal and Telford premiums.

The HOWARD QUINQUENNIAL PRIZE for 1882 to Sir William Siemens, F.R.S., M. Inst. C.E., in consideration of his important discoveries, and of the valuable improvements he has effected, in the manufacture of Iron and Steel.

FOR PAPERS READ AT THE SUPPLEMENTAL MEETINGS OF STUDENTS.

1. A Miller Prize to Henry John Eunson, Stud. Inst. C.E., for his Paper "On a Deep Boring at Northampton."
2. A Miller Prize to Percy Vavasseur Appleby, Stud. Inst. C.E., for his Paper "On Iron and Steel in Tension, Compression, Bending, Torsion, and Shear."
3. A Miller Prize to Arthur Beckwith, Stud. Inst. C.E., for his Paper on "Refrigerating-Machinery,"
4. A Miller Prize to Thomas Stephen Lacey, Stud. Inst. C.E., for his Paper on "The Illuminating Power of Coal-Gas."
5. A Miller Prize to Henry Hollingworth Parkinson, Stud. Inst. C.E., for his Paper on "The Transportation, Storage, and Shipment of Grain."

SUBJECTS FOR PAPERS.

SESSION 1883–84.

THE COUNCIL of The Institution of Civil Engineers invite Original Communications on any of the Subjects included in the following list, as well as on other analogous questions. For these, if approved, they will award Premiums, arising out of Special Funds bequeathed for the purpose, the particulars of which are as under:—

1. The TELFORD FUND, left "in trust, the Interest to be expended in Annual Premiums, under the direction of the Council." This bequest (with accumulations of dividends) produces £260 annually.
2. The MANBY DONATION, of the value of about £10 a year, given "to form a Fund for an Annual Premium or Premiums for Papers read at the meetings."
3. The MILLER FUND, bequeathed by the testator "for the purpose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) realises £150 per annum. Out of this Fund the Council have established a Scholarship,—called "The Miller Scholarship of The Institution of Civil Engineers,"—and are prepared to award one such Scholarship, not exceeding £40 in value, each year, and tenable for three years.
4. The HOWARD BEQUEST, directed by the testator to be applied "for the purpose of presenting periodically a Prize or Medal to the author of a treatise on any of the Uses or Properties of Iron or to the inventor of some new and valuable process relating thereto, such author or inventor being a Member, Graduate, or Associate of the said Institution." The annual income amounts to rather more than £16. It has been arranged to award this prize every five years, commencing from 1877. The next award will therefore be made in 1887.

The Council will not make any award unless a communication of adequate merit is received, but will give more than one Premium if there are several deserving memoirs on the same subject. In the adjudication of the Premiums no distinction will be made between essays received from any one connected with the Institution (except in the cases of the Miller and the Howard bequests, which are limited by the donors), or from any other person, whether a Native or a Foreigner.

List.

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Cleburne, James	3	3	0
Clegg, C.	2	1	0
Clemmey, W. H.	1	1	0
Corry, J. E.	0	10	6
Cotton, C. O.	2	2	0
Croft, Henry	2	2	0
Cross, A. W.	1	1	0
Culverwell, G. P.	2	2	0
Curling, A. H.	4	0	0
Cutbill, W. J. C.	5	5	0
Davison, T. V.	1	1	0
Dawnay, A. D.	5	5	0
Dawson, W. A.	2	12	6
Dent, H. C.	1	1	0
Depree, C. L.	2	12	6
Fahie, W. J.	3	3	0
Francis, Joseph	1	1	0
Fyson, Alfred	2	12	6
Gatherer, A. B.	10	10	0
Gordon, Major E. S.	10	0	0
Griffin, B.	1	1	0
Gumbley, W.	1	1	0
Hanson, C. R.	2	2	0
Harris, Richard	5	5	0
Harris, R. Reader	1	1	0
Hart, J. W.	2	2	0
Hawkins, R. W. L.	2	2	0
Carried forward	137	3	6

	£.	s.	d.
Brought forward	137	3	6
Heaphy, T. M.	1	1	0
Henderson, H.	1	1	0
Henslowe, C. W. E.	5	5	0
Holden, J.	1	1	0
Holt, Arthur	2	2	0
Hudson, J. C.	1	1	0
Leather, S. P.	2	2	0
Ledger, J. C.	1	1	0
Lockhart, W. S.	1	1	0
Mackay, J. C.	1	1	0
Macrae, John	5	5	0
Manuel, D.	2	2	0
May, J. G.	1	1	0
Morgan, C. L.	5	5	0
Nightingale, W. H.	2	2	0
Normanville, W.	1	7	6
Parkinson, R. M.	2	2	0
Powell, E.	2	2	0
Prestige, S.	1	1	0
Rendel, W. S.	2	2	0
Rigby, Jason	5	0	0
Roberts, T.	1	1	0
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Ross, J.	1	1	0
Rutherford, H. K.	1	1	0
Santos, J. A. dos	3	3	0
Sells, C. de G.	2	2	0
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Sumner, H. G.	1	1	0
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Veitch, D. D'A. W. (*the late*)	1	1	0
Voysey, H. W.	1	1	0
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* *This Council will continue till December* 1884.

SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 1893.*)

"On the Mining and Treatment of Gold Ores in the North of Japan."

By ROBERT JAMES FRECHEVILLE, Assoc. M. Inst. C.E., H.M. Inspector of Mines for Cornwall, Devon, &c.

IN the northern part of Hondo, the largest of the Japanese Islands, about mid-way between the eastern and western seaboards, and some 60 miles to the south of Awomori Bay, are situated the Okudzu Mines, where a number of small veins enclosed in a porphyritic rock have been worked for gold from time immemorial.

These veins vary in width from 2 or 3 inches to as many feet, the average width being about 1 foot, and are filled with quartz and decomposed country rock carrying disseminated crystals, and thin bands of copper and iron pyrites, together with small quantities of zinc blende and galena. The gold contained, which is in such a finely divided state that without pulverizing and washing the ore it can scarcely ever be detected in the richest specimens, even with the aid of a magnifying glass, ranges from a mere trace up to several oz. per ton. The richest classes of ore also often have telluride of gold associated with them.

The district being mountainous has enabled these veins to be worked by means of adit levels to a depth of about 120 fathoms below their outcrop. In driving these adits, the deepest of which has a length of over 1,400 fathoms, advantage has been taken of a soft clay cross-course, which intersects the lodes, and has heaved them 40 or 50 fathoms; close to this cross-course the lodes were most productive, and have been extensively mined, whilst some little distance off they decreased in size and became hard and poor.

The miners worked both on tribute and tut-work by single-handed drilling with powder as an explosive; safety fuse was also used; the holes bored were about 1 inch in diameter, and 14 inches in depth; light was furnished by torches made of dried bamboo twigs; all the ore raised was carried to the surface in straw bags by women and girls; and was transported in like manner from the mine to the dressing floors, situated in a valley about 1½ mile distant on the banks of a small river. The miners earned an equivalent of about 1*s.* per day, and the ore carriers from 4*d.* to 6*d.* per day.

About 120 tons of ore of an average grade of 1½ oz. of gold per ton were produced per month, at a cost of about £4 per ton delivered at the floors, the high price being due to the scarcity of this ore remaining above the level of the deep adit, the narrowness of the veins, and the difficulties of underground transportation, caused by the great length of the levels and travelling roads, and their small size, it being just possible in many places to crawl through and no more. A considerable quantity of ore of a grade of about ½ oz. of gold per ton still remained in the mine, but owing to the wretched manner in which it was opened out could not be removed at a profit.

The richest ore was treated by the Japanese gold-washing process, which was entirely carried out by women. The ore was first pounded under stamps resembling a tilt-hammer (Plate 6, Fig. 1), the stamp-head being affixed to the short arm of a lever, while the motive power was given by the foot to the long arm; the coffer consisted of a block of hard stone hollowed out in the centre. When reduced to a coarse powder, the ore was ground together with water under flat stones similar to the ordinary flour-mill, but rotated by the hand (Fig. 2). The sands and slimes produced flowed by means of a spout into a little bowl placed at the head of an inclined plane about 12 feet long, formed of three scored boards, each 4 feet long, and 1 foot wide, set at an angle of 12°. These scored boards (Fig. 3) were made by taking a smoothly-planed plank, and marking it with a saw, which was held inclined towards the head of the board at an angle of 60° from the horizontal. The saw-cuts were 1 inch apart and $\frac{1}{12}$ inch deep. An additional supply of water flowed into the bowl at the head of the inclined plane, the diluted material passed over the boards, the heavier particles remained in the furrows or saw-cuts, and were removed by washing and knocking the boards in a tank of water; the sands and slimes escaping from the ends of the boards fell into a tub, which retained the coarser portion, whilst the slimes flowed over the edge into pits, from which they were occasionally shovelled out and rewashed. The coarser sands caught in the tub were reground. By this means from 50 to 60 per cent. of the ore treated was changed into slimes. The concentrations from the boards were washed out by hand in a slightly concave wooden dish, about 18 inches square. The gold obtained was melted with borax and lead, and the product cupelled. The rich residues from the hand-washing were reground, and again subjected to concentration on the boards. As can readily be imagined, in spite of the cheap labour, the women receiving only about 3*d.* (5 sen Japanese) per day, the process was an expensive one, and very limited as to the amount of mineral treated. About 10 tons per month were pulverized and washed as described at a cost of £2 per ton. The results obtained varied according to the grade of the ore, about 50 per cent. of the gold being got by the first washing from ores of 2 oz. per ton, and about 80 per cent. from the richest class of ores, which assayed at the rate of 5 oz. per ton and upwards. The tailings, after being exposed for some time to the action of the atmosphere, were rewashed, yielding a further amount of gold. From the above it is apparent that in these mines only the richer classes of ores could be mined and washed by the Japanese processes at a profit.

In order to increase the output of the mines, and enable the poorer classes of ores to be utilized, the Japanese Government ordered a ten-stamp gold-mill from San Francisco. This was erected by an American engineer, who unfortunately died just as the works were completed; the Author was then instructed to proceed to the mines, and put the mill in operation. He found it to be of the usual Californian pattern, intended for battery and copper-plate amalgamation; the sands and slimes produced by the stamps flowed over 20 feet in length of amalgamated copper plates, and the tailings through Hendy's concentrators, the produce being amalgamated in two flat-bottomed grinding pans of a capacity of 1,000 lbs. of ore each per charge.

As the ore contained gold in an excessively finely-divided state, associated with from 10 to 20 per cent. of sulphurets, this process failed to give satisfactory results, by far the greater portion of the gold escaped amalgamation in the mortars and on the plates, and passed to waste in the finest slimes on which the Hendy's concentrators would not act. The Author therefore determined to concentrate before amalgamation, and as the first principle in concentrating stamp-work consists in assorting or classifying the sands, he led the pulp (crushed ore with water), from the mortars directly into a slime-separator.

The ten stamps, each of which revolved automatically and weighed complete 750 lbs., were contained in two mortars, and were driven at a speed of 60 blows per minute, with a 9-inch drop, discharging through iron wire screens with 1,600 holes to the square inch. Some difficulty was experienced at first from the choking of the sieves, caused by pieces of bamboo from the torches used in the mine being mixed with the ore; this was effectually prevented by enclosing the sieves on the outside with boards, leaving a space of 3 inches between the boards and screens, so that the water stood level on each side of the screens, the pressure being thus equalized. The bottom of this compartment was inclined from both sides towards the centre. At the lowest point there was an opening adjustable by a slide-gate, by means of which the discharge and the height of water in the mortars was regulated. The stamps crushed from 10 to 12 tons per twenty-four hours, or a little over 1 ton per stamp. The slime separator "Spitz-Lutte" for classifying the stamped ore depended for its action on the falling of the denser portion of the stuff through an ascending current of clear water, which at the same time carried the slimes upwards and out of the apparatus. It was made by inserting a wedge in a wedge-shaped box (Figs. 4 and 5), leaving a space of 4 inches between it and the inclined sides of the box; in the interior of the box at the bottom two funnel blocks c c were fitted, so that there was an opening 2 inches square connecting with the pipe *e*, $\frac{3}{4}$ inch in diameter. Clear water was admitted by the pipe *d*; the sands and slimes entered at A, passed down the space B, and came within the influence of the ascending column of water; the coarser and heavier grains fell through the funnel, were carried along the pipe *e* up the pipe *f*, and discharged through the mouth-piece *h*, $\frac{5}{8}$ inch in diameter; whilst the lighter sands and slimes which could not sink through the ascending clear water, were carried up K, and discharged at *m*. By varying the height of the mouth-piece *h*, and its diameter, the size of grain and the quantity of the sands separated were to some extent regulated.

The sands, which amounted to about 50 per cent. of the ore stamped, were concentrated on Rittinger's double side-blow percussion table, the concentrates being subsequently amalgamated in the pans.

Fig. 6 is a plan, and Fig. 7 a front view of the table, 8 feet square, made of boards planed smooth and divided into two parts, by means of a strip of wood *a*, similar strips *b* being placed on the sides. It was suspended by four iron rods *c*, at an angle of 6°. The inclination could be varied by means of the screws *d*. A heavy beam of wood *e* was bolted to the middle of the underside of the frame of the table, projecting some distance beyond it on each side; to one end of this beam was attached the wooden spring *f*, which could be screwed nearer to the frame *g*, thus increasing the strength of the stroke, whilst to the other end of the beam was attached the arrangement *h* for regulating the length of the stroke, shown on a larger scale in Figs. 8 and 9. Motion was imparted to the table by the rods *i* connected by the perpendicular rod *k* with the tappet *m* on which the cams acted. The percussion was produced by the striking of the heavy wooden beam *e* against the block *n*.

The spring *f* had a tension of about 180 lbs., the length of stroke was 1½ inch, and the number of strokes 120 per minute.

The sands from the classifier came on the distributing board at P, and clear water at Q. Under the influence of percussion and the flow of water, the heavier particles of ore collected in curved lines, and were discharged at R, whilst the lighter gangue followed nearly straight down in the course of the water, passing off the table to waste at S; between these two there was a middle product obtained at T, which was reconcentrated. The movable tongues *w* regulated the quantity of material in either class, and were secured in their places by means of thumbscrews. One double table treated from 2½ to 3 tons of classified sands per twenty-four hours, and acted very well.

The lighter sands and slimes separated by the "Spitz-Lutte," and discharged at *m*, Fig. 4, were conveyed by a launder to twelve Hungarian mills, arranged in two rows of six each, set one above the other, so that the lower row should receive the slimes from the upper. Fig. 10 gives a side view of these mills, one mill being shown partly in section; they were made of wood bound with iron, and were lacquered on the inside, having a depth of 5 inches, a diameter at the bottom of 15 inches, and at the top of 23 inches, inside measurements. The discharge was 3 inches above the bottom. Each mill held 56 lbs. of mercury, or a depth of that metal of ¾ inch round the central cone, and ½ inch round the sides. Between the runner and the surface of the mercury there was a space of ½ inch, and a like space between it and the sides of the mill. On the underside of the runner a number of strips or wings of iron, Fig. 11, were arranged radially as shown in Fig. 12, so as just to touch the surface of the mercury and clear the sides of the mill. The runners made from 18 to 22 revolutions per minute; the slimes were carried over the surface of the mercury by the centrifugal action developed, and were finally discharged into the lower mills, and from them into the launder B. At the close of each run the mercury was drawn off and strained, the amalgam obtained being retorted.

From the launder B, as no blankets or hides were procurable, the slimes passed over strakes 40 feet long, set at an angle of 7½°, covered with scored boards, so arranged that the slimes always flowed over a width of 8 feet of boards. These boards were each 5 feet long and 1 foot wide, the tail of one fitting into the head of the other. The first two rows of head boards were washed every half hour, the second two rows every hour, and the last four rows every three hours. Although it required a great deal of labour to remove and wash the boards, they acted excellently in saving the fine gold.

The amalgamation of the concentrates from the percussion-tables and boards, which amounted to about 10 per cent. of the ore stamped, was performed in two flat-bottomed iron grinding-pans, each having a capacity of from 800 to 1,000 lbs. of ore per charge, or a little over 1 ton per pan in twenty-four hours. These pans made from 50 to 60 revolutions per minute, and after being charged with the right amount of water and concentrates, the mullers were gradually lowered, and grinding went on for about three hours, steam having meantime been admitted into the pulp, so that its temperature was about 150° Fahrenheit. Quicklime was next added to neutralize any sulphates that might have been produced. The mullers were then raised ½ inch from the dies, and about 100 lbs. of mercury added to each pan; amalgamation then went on for four hours, when the contents of the pans were discharged into the settlers for collecting the mercury, and the pans themselves being thoroughly washed out with clean water were ready for a fresh charge of concentrates.

The slimes from the settler, after passing through agitators, which saved a further amount of mercury, were carefully stored in pits for retreatment. The amalgam collected was retorted, and the gold melted into bars in the usual manner.

The pan-amalgamation gave over 90 per cent. of the gold contained in the concentrates, and the result of the combined treatment by concentration and amalgamation was an average of 82 per cent. of the gold contained in the ore milled, which had an average assay-value of 1½ oz. per ton. Of the gold obtained about one-third was saved by the Hungarian mills, and the remainder by the pan-amalgamation of the concentrates. Samples of the ore and tailings were taken both by day and night, and assayed so as to check and control the working of the mill. The gold which escaped concentration and amalgamation was contained principally by the copper pyrites, which on stamping formed a very finely divided slime that would float on the surface of the water; some gold was also carried away by floured mercury.

A horizontal engine, with cylinder 15 inches in diameter, and a stroke of 2½ feet supplied the power for working the mill, steam being furnished by a 40-HP. multitubular boiler.

The apparatus and machinery were made at the mine by Japanese blacksmiths and carpenters; the mill was also worked entirely by Japanese, who, for intelligence and attention to details, are not to be surpassed by the workmen of any country.

As to the cost of milling, the Author is unable to give exact figures, it being always difficult to do so when new works are started; more especially so in this case, where all material, such as castings, mercury, crucibles, &c., had been supplied from the United States, but probably it did not exceed 8*s*. per ton.

In November, 1876, the Author returned to Yedo, and the ore which had accumulated during the erection of the mill, having been stamped, and no steps having meantime been taken to properly lay open and develop the mines, they have since proved unable to supply the quantity of ore required by the works.

The Paper is accompanied by several drawings, from which Plate 6 has been prepared.

(*Paper No. 1948.*)

"Discharge of Streams in Relation to Rainfall, New South Wales."

By Timothy Augustine Coghlan, Assoc. M. Inst. C.E.

The country watered by the Upper Nepean, Cordeaux and Cataract rivers, comprises an area of 354 square miles, the mean length from north to south being about 25 miles, while the width from east to west is on the average 16 miles. It is for the most part uninhabitable, and has been reserved by the Government of New South Wales as the source from which the city of Sydney with its suburbs is in future to derive its supply of water. The area included within the catchment of these rivers lies on the western side of the range of mountains constituting the watershed between the Nepean Valley and the Illawarra district, and is in no place distant more than 20 miles from the Pacific Ocean. The ridge forming its eastern boundary is known as the Illawarra or Mittagong range, and has an average height of about 2,000 feet above sea-level; the most noteworthy peaks being Mounts Keera and Kembla, opposite the town of Wollongong. The average elevation of the basin is probably not less than 1,200 feet above the sea. On the eastern side of the basin to the lee of the mountains the country is flat; numerous swamps retain the water and serve to some slight extent as a storage reservoir, by equalising the flow and gradually feeding the tributary streams at the head of the rivers. The swamps occur chiefly in the Cataract part of the watershed, and though considerable in themselves do not occupy a very large portion of the area. The remainder is a rugged plateau intersected by steep and broken ridges, which sometimes rise perpendicularly from the beds of the streams. The whole country is barren; the surface-soil is poor, resting in many places almost directly on sandstone, which crops out on the sides and tops of the spurs of the hills and in the beds of the streams. Vegetation is represented by stunted varieties of eucalyptus and epacris, though the scrub is in many places thick; in the valleys and in other choice spots the common gum trees attain goodly proportions.

The main branch of the Nepean rises at the extreme south of the watershed at a point nearly 2,400 feet above the level of the sea, whilst the sources of the Cordeaux and Cataract have an elevation of about 1,400 feet. The rivers, though they rise far apart, converge till the Cordeaux unites with the Nepean at the Pheasant's-Nest Pass, after a course of about 24 miles, the length of the Nepean being about 30 miles. Below the junction of these rivers a weir was erected to gauge their united waters. The Cataract approaches the Nepean nearly at right angles, and at Broughton's Pass, 20 miles from its source, at the site of a weir, it is only 4¾ miles distant from that river. Here a tunnel is being pierced to divert part of the Nepean and Cordeaux waters to the Cataract, to be thence conducted to Sydney.

Both the Pheasant's-Nest and Broughton's Pass are gorges in the sandstone hills, their sides rising sheer. The fall along the bed of the Nepean is about 70 feet, and of the Cataract nearly 60 feet per mile. The rivers near their sources descend from the hills in miniature cascades. The lay of the basin of these rivers is north and east. To this must be attributed the equable fall of rain over the basin. The records of a long series of years establish the fact that the rain is more copious near the coast than inland, and that the average depth of rain at a particular place generally depends on its distance from the sea.

At Sydney the heavy rainfalls, brought by the south-east winds, are attributable to the peculiar situation of the adjacent district forming part of a region of precipitation, of which the Nepean and Cataract basin is the extreme south. Long since, the Government Astronomer of New South Wales pointed out, that on the border of the south-east trade, as on that of the north-east, there is a belt of calms, or changeable winds, and that the polar side of this belt is the region of precipitation. Port Macquarie, in lat. 32° 47′ S., is usually the limit of the south-east trade-wind on the New South Wales coast. Thence southward for a few degrees the rainfall is excessive. The configuration of the Nepean and Cataract basin is, moreover, such as to promote the discharge of the rain brought by the trade-winds; while on the other hand, the clouds gathered by the southerly winds discharge their moisture on the western or lee side of the coast ridge, which has just sufficient elevation to obstruct the passage of the clouds and facilitate precipitation.

Rain-gauges have been established at various points in the river-basins. The values, in Appendix, Table I., are not for one place; but the adjusted means for the whole district, giving due weight to the area represented by each gauge. The annual fall of rain varies from 75 inches to 34 inches. The average fall since 1869 has been about 54 inches at the Cataract river, while at the Nepean it has been only 44½ inches, or about 82 per cent. of the former. This average holds good both for a series of months and years, the excess on the Cataract basin being attributable to its closer proximity to the sea, the dividing ridge being there only 3 miles distant from the Pacific Ocean; and also to its trending towards the direction from which the heaviest downpour comes. Table I. shows the proportion of water falling on the two basins.

The area of the Nepean basin is about 284 square miles, and of the Cataract about 70 square miles, the proportion being as 4·06 to 1. The average rainfall is as 0·825 to 1; thus the proportion of rainfall over the Nepean area to that of the Cataract is as 3·35 to 1.

The heaviest rain observed during any month was in February 1873, when 22·43 inches fell on the Cataract, and 19·78 inches on the Nepean basin; the least was in April 1871, when 0·24 inch and 0·10 inch of rain fell at these places. Most of the rain falls from February to July, though heavy rains sometimes occur in September and October. Excessive falls are often due to great rain-storms in the latitudes just beyond the south-east trades. On the 26th of February, 1873, 11 inches of rain were recorded in twenty-four hours; but cases have been known at Sydney where a depth of 20 inches has fallen in twenty-four hours. The average number of rainy days for the year is one hundred and forty; the number of days of continuous rain has been twenty-six, and periods of seven days continuous rain are not unfrequent. Droughts are, unfortunately, also of long duration; thus from July 1875 to April 1876, a period of two hundred and eighty-seven days, the total depth of water falling on the Nepean basin was only 14·93 inches; and from February to October 1872, being two hundred and thirty-five days, only 10·43 inches fell. The longest time without rain was about twenty days.

The annual evaporation varies from 70 to 30 inches, the mean being 48 inches. These figures are somewhat in excess, as the circumstances under which measurements to ascertain evaporation are made bear little analogy to that of water from lakes, swamps, or streams. Bearing this in mind, the annual evaporation from water exposed to the direct effect of the sun may be taken as about 36 inches. But in a country covered with thick scrub, as here, evaporation from the ground is not so considerable as is sometimes supposed. Rain is effective, not so much in direct proportion to the volume falling, as according to the distribution of that volume. For instance, at the Cataract River 75 inches in 1873 produced less discharge than 64 inches in 1870; again, 54 inches, which fell in each of the years 1871 and 1874, gave rise to almost the same discharge, while a similar depth of rain in 1875 produced much less flow. In regard to the exceptional discharge of 1870, in the months during which the greater part of the rain fell, it rained nearly every day; the ground was saturated, and the water ran off to the streams before evaporation and soakage could take place. During 1874 the discharge was high; the previous year had been wet, particularly in the latter months, and in the first six months of 1874 a considerable depth of rain also fell, the latter half year being dry. In 1875, though the first period of the year was wet, the previous months of 1874 had been dry, and the rain was for that reason not effective.

With regard to the ultimate destination of the rain, assuming 44 per cent. to pass off by streams, as will hereafter appear, the depth of water annually evaporated is 36 inches out of a rainfall of 54 inches, or 66 per cent. This would be, of course, impossible, in view of the volume yielded to the streams: but there are many causes operating to diminish evaporation, by preventing the direct action of the sun, so that in all likelihood the water re-evaporated does not amount, on the average, to much more than 33 per cent. of the rain, the remainder, after deducting the stream-discharges, escaping under ground. No rule can be laid down in regard to this matter, as the possible evaporation is always greatest when the rain is least, the maximum rainfall being accompanied by the minimum of evaporation. The observations seem to indicate that in years of abundant rain, not more than 15 per cent. of the rain is re-evaporated, the remainder going to feed the streams, or being absorbed by the soil. In years of low rainfall the amount of evaporation is from 50 to 60 per cent., while during average years 33 per cent. would represent the rain thus lost. Regarding the disposal of rain underground, part is returned to the rivers by springs through crevices in the rocks, part is absorbed by vegetation, and part is carried away through fissures in the rocks or breaks in the strata, to places below the streams. Tunnels and openings in the Sydney sandstone show that waste from this last source is considerable.

The positions of the weirs are shown in Plate 7. Convenient points were chosen for the erection of these weirs, the rivers being dammed by planks of Oregon pine, 2½ inches thick, bolted to the rock in the bed of the river and calked with oakum. The notch at the Cataract was 3 feet 6 inches, and at the Nepean 10 feet wide, both being 1 foot deep. The formula given by Rankine,

$$Q = 5\cdot 35\, c\, b\, h^{\frac{3}{2}}$$

was used in calculating the discharge when the water falling over the weir was less than 1 foot deep, c being considered as 0·598; thus the formula reads

$$Q = b\, h^{\frac{3}{2}} = \text{cubic feet per second.}$$

When the water rose over the top of the notch to a moderate height, the discharge was taken as that of a drowned weir. Elaborate observations were made to ascertain the discharge of the rivers when in flood; various cross-sections were taken, and the velocities measured, at the different flood-heights when opportunity offered, and the results for each cross-section were compared. The inclinations of the rivers were also recorded at suitable points, the probable discharges calculated therefrom, and the new results compared with the former ones, and with one another, and in this way a Table of the probable discharge at each foot in height was arrived at. The results hereafter stated may be considered fair approximations of the discharges of the rivers.

Gaugings were commenced towards the close of the year 1868, and they are still carried on. From this period of upwards of fourteen years, during the interval from July 1869 to June 1876, which has been selected as containing illustrations of all the circumstances that need remark, the average annual depth of rain was 53·99 inches on the Cataract basin, and 44·28 inches on that of the Nepean,[1] the proportion being as 1 to 0·823; but as the area of the basin of the former river was hardly one quarter of the latter ($\frac{70}{284}$), the proportion of rain falling on each district was as 1 to 3·34. The average yearly discharges were 24,484,000,000, and 80,383,000,000 gallons, equivalent to 24·14 and 19·54 inches of rainfall respectively, or allowing for the superior area of the Nepean as 1 to 3·28.

The records of rainfall and discharge for any particular year show, that the dry years are somewhat in favour of the smaller area, while the wet years give either corresponding results, or are in favour of the Nepean. It has been usual to assume that the proportion would be in favour of the smaller area, this proportion being reckoned as a to $A^{\frac{3}{2}}$, where a = discharge per unit of the smaller

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[1] These figures differ slightly from those given above; the time from which the average is taken is not quite the same.—T. A. C.

and A that for the larger area. The observations taken at the Nepean and Cataract rivers, on the contrary, indicate that the total flow of water from similar districts is in proportion to the volume of the rainfall and the area of each district, bearing in mind always that there is no great disparity in the two areas. The proportion between rainfall and discharge is, in the case of the Cataract, 44·7 per cent., while in the Nepean it is 44·1 per cent. for an extended period, including every condition of flood and drought. This is a much larger proportion than is generally reckoned on; but, if there be any error, it is on the side of being short of the full quantity, owing to the rapidity with which freshets rise in districts of heavy rainfall, and the difficulty of measuring their volume, The average of freshets is about 54 per cent. of the rainfall, while after the ground has become saturated with previous rain, the volume discharged is nearly equal to the quantity of rain falling. In dry seasons the volume of the streams bears but a small proportion to the depth of rain, from 10 to 12 per cent. being the average yield. In the Appendix, Tables II. and III. show various comparisons between the two streams in regard to the rainfall and the flow due to that rainfall, from which it is evident that their discharges, notwithstanding the difference in drainage areas, is in proportion to the rainfall, the dry periods being decidedly in favour of the smaller area; but the quantity of rainfall and water carried off by the streams in droughts is so small, that when the whole is comprised the discrepancy is not shown.

Rejecting the incomplete years 1869 and 1876, it will be seen in the Nepean River, when arranged (*a*) according to the rainfall, (*b*) the discharge, and (*c*) the proportion of rain discharged (the years giving the largest results being placed first on the list), that for the Nepean River, the years come in the order shown in Table IV. The result of the grouping shows that the greatest rainfall is attended by the greatest discharge, and also by the greatest proportion of discharge to rainfall; and not only so, but the years follow in every case in their proper order. Of course this cannot be looked upon as other than a coincidence, remarkable certainly, but still only a coincidence. Turning now to the Cataract, the years in the same way are as shown in Table V. This is satisfactory, except in respect to 1873, which was a year of abundant rain, though the flow was not proportionate to the rain. The deduction to be derived from this and the preceding Table is obvious. The quantity of water carried off by a stream is not directly proportional to the rainfall; but the greater the quantity of rain falling within a given time, the greater is the percentage of that rain carried off by the streams.

In rainy periods the greatest floods, not only actually, but proportionately to area of basin, were experienced first in the Nepean, notwithstanding its area was four times as large as that of the adjacent stream; though during the whole time of flood almost similar proportions of the rain were measured as given off by the two streams. This may be accounted for by the existence of large swamps in the Cataract district, which act as flood-moderators; whereas in the Nepean very little of the rain is retained by the swamps; to this fact likewise must be attributed better results from the dry-weather discharge of the Cataract.

Experience elsewhere has led to the conclusion, that flood-volumes are proportionately greater for smaller areas, and formulas have been constructed on this basis; but the experience derived from streams in New South Wales does not favour this assumption, though it may be correct in the main. The great floods of the Nepean rise 60 feet, but remain at that height only a short time; for instance, on the 23rd of February, 1873, the Nepean flowed 1·20 foot over the sill of the weir; on the 24th, 4·15 feet; on the 25th about the same; but on the 26th, a depth of 55 feet of water was measured at eleven o'clock, and of 60 feet later in the day; twenty-four hours afterwards the depth was 30 feet; on the 28th the river ran 10 feet deep, gradually falling to 4 feet five days afterwards. The quantity passing down during the height of the flood in twenty-four hours was probably 30,000,000,000 gallons, which would make the coefficient c in the formula:—

$$\phi = c \times 27\ (M)\ \tfrac{1}{2}$$

equal to 120 instead of 28 as usually adopted.

By Fanning's formula,[1] where

$$\phi = 200\ (M)\ \tfrac{5}{6}$$

ϕ = cubic feet per second and M = area of watershed in miles, the result is about 12,000,000,000 against 30,000,000,000 gallons as above stated. This was an extraordinary instance, floods in general being not more than 40 feet over the sill giving a daily discharge at the top of the flood of about 18,090,000,000 gallons, a quantity much beyond the scope of the formula.

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[1] "A practical treatise on Water-supply Engineering," p. 66.

The Nepean River, therefore, hardly comes within the limits contemplated by the Authors of these formulas, though in the Cataract there is a nearer approach to the result derived from the formula. In the latter stream the flood rises 24 feet, and discharges a volume in twenty-four hours of 3,787,000,000 gallons, while the formula of Fanning gives 3,768,000,000 gallons.

No attempt is here made to bring flood-volumes within the bounds of a rigid mathematical formula, there being no agreement between the two rivers to admit of such, especially as the principle, that the floods of the larger area are proportionately less than those of the smaller, would be violated. But though in isolated floods no agreement is observable, yet in the general results of large and small flows, as compared with the rainfall, there is ample evidence of the operation of fixed laws.

From the 28th of August, 1869, when both streams were low, till the 1st of May, 1876, the end of a long-continued drought, a succession of freshets occurred over periods varying from three hundred and six to fourteen days, alternating with intervals of small flow, the longest of which was two hundred and eighty-seven days. The total quantity of rain causing floods or freshets during these periods was, in the Cataract River, about 290·98 inches, of which 153·86 inches, or about 53 per cent., flowed over the sill of the weir. In the Nepean basin 239·87 inches fell, and 124·17 inches, or 52 per cent. of this quantity, passed down the stream, the percentage being nearly the same in each case. The largest ratio of flow to rainfall in the Cataract was nearly 70 per cent., the least for any considerable time was 26·6 per cent. In the Nepean the largest proportion was 67·76 per cent., the lowest 23·6 per cent. The total time occupied by freshets was eleven hundred and sixty-two days, and that reckoned as ordinary flow was eleven hundred and one days. The average rainfall for the Cataract during freshets was 0·25 inch per day, the quantity carried off giving an equivalent of 0·133 inch per day. At the Nepean the average rain amounted to 0·207 inch, the quantity discharged being equivalent to a little more than 0·107 inch. Tables VI. to VIII. in the Appendix contain an analysis of the measurements of the various freshets in the order in which they occurred for the Cataract River, and Tables IX. to XI. for the Nepean River. The results of Tables VI. and IX. are grouped under two series marked *v* and *x*, and *y* and *z*. These are arranged according to the length of the freshets in Tables VII. and VIII., and X. and XI.

Neither in the case of the Cataract nor the Nepean are the Tables perfectly symmetrical; but the broad fact remains, that during freshets the proportion of water carried off by a stream is greater or less according as the time during which the freshets last is longer or shorter, other things being equal. This law is apparent not only in the gaugings whose results are herein presented, but in the whole series from 1868 to the present time.

The formula, used by the Author for the calculation of the quantity of water due to freshets for natural drainage-districts of moderate size, is an empirical one, but can be relied on fairly well within certain limits; it is—

$$P = t\,c\,R^{1\cdot 9}.$$

Where P = inches of rainfall discharged by streams.
t = coefficient for time, the value of which is governed by the length of time the freshets last (Table XII.).
c = coefficient of rainfall varying with the quantity of rain (Table XIII.).
R = average daily rainfall in inches during freshet.

Not less important than the observation of streams in flood is the determination of their ordinary flow; in fact the latter is of greater moment to an engineer seeking for an efficient water-supply. For the eleven hundred and one days of ordinary flow, the rainfall was 73·74 inches at the Cataract, and 59·42 at the Nepean River, being an average daily fall of 0·070 and 0·055 inch. The rain yielded a gross equivalent flow of 8·73 and 5·90 inches, or a percentage of 11·8 in the one case, and of 10·0 in the other. Statements of the different low discharges are arranged in the order of occurrence in Tables XIV. and XV. Both these Tables are to some extent inconsistent. The cause lies in the difficulty of determining the exact time when a dry period begins. No matter how low the water may be in the streams, there is always some water due to the wet period preceding the dry one. This cause of error also operates in rainy weather, but not to a serious extent, as the water due to previous rain forms but a small portion of the whole flow, whereas in the case of low discharges this item may be a factor sometimes to the extent of 50 per cent. The practice followed by the Author is to count as available only 10 per cent. of the rainfall for periods of small flow up to one hundred and fifty days; for the succeeding fifty days the amount taken is 8 per cent.; for the following fifty days, 6 per cent., and for the next fifty days, 4 per cent. This gives three hundred days in a period of exceptional drought. The above is less than the practice generally obtaining elsewhere, but it is warranted by the frequently great heat of the dry summers. During the drought in 1875–76, which lasted for more than nine months, the discharge at the Nepean River in the first half of the period, after deducting the water due to previous rainfall, was equal to about 9 per cent. of the rain; whilst during the latter part the discharge was only equal to 4 per cent. The Cataract during this time yielded a still smaller percentage.

The conclusion to be drawn from the gauging in seasons of small flow is, that for periods of like rainfall the discharge of the streams is greater or less, according as the time over which the rainfall extends is less or greater. This general rule is subject to modification from various causes, the chief being the extent of evaporation, and the volume of rainfall within short periods, such exceptions not invalidating the general principles laid down as to relative discharges.

Regarding the economical size of the channel to deliver water from streams to a storage at some distance, it is difficult to define exact rules, as the useful discharge depends greatly upon the equable distribution of the rain throughout the year, and on the retention of large quantities of water in swamps, sand-drifts, or such-like natural reservoirs, until delivered to the streams, when they begin to fall off in volume.

Perhaps as good an example of natural storage as could be found is afforded by the Botany and Lachlan swamps, whence the city of Sydney at present draws its supply of water. The swamps and sand-drifts now comprise an area of about 8 square miles, though for years the area supplying Sydney was not more than 5¾ miles. From the latter area a supply of water has been drawn equal to about 18 inches of rain, while the total depth of rain on the average is not much more than two-and-a-half times that quantity. From the 1st of January to the 8th of April, 1876, the latter portion of the drought, during which scarcely 12 inches of rain fell in nine months, and only 4·10 inches in the above-named period, the water in the swamps was carefully gauged, and it was ascertained that the amount drawn off for consumption was about 400,000,000 gallons; the volume of water lost by evaporation in excess of rainfall may be taken at 116,000,000, whilst the quantity available within the dams at the end of the period was 51,000,000 gallons, giving a total of 567,000,000 gallons used or available for use during this period. Against this quantity is to be set the water in the various reservoirs upon the 1st of January, 1876, which amounted to 173,000,000 gallons, leaving 394,000,000 gallons unaccounted for. This represents an equivalent of about 7 inches of rain over the whole available Botany portion, comprising an area of 4 square miles. It was drawn entirely from the sand, and as the water-levels on the inner side of the dams were reduced, the water pouring in from the sand increased in volume, so that in April the discharge was 500,000 gallons per day more than at the beginning of the year, whilst the rainfall was so small as to be negligible.

In the Nepean and Cataract rivers an equable flow depends almost entirely upon the distribution of the rain; thus at the Cataract, 75 inches of rain in 1873 were of very little more value for water-supply than 54 inches in the following year. This was owing to the rainfall in 1874 having been better distributed than in the previous year.

If the average daily volume of a stream be taken as a standard, and a channel be assumed as capable of carrying off the whole of this quantity, provided the stream was of the same dimension each day, the actual discharge of such a channel would be about 41 per cent. of the whole discharge of the stream, the remaining 59 per cent. not being available from the floods bringing down a far greater body of water than the channel could carry off, even though its capacity were equal to the mean discharge. If the capacity of the channel were one half the mean daily discharge, it would convey 26 per cent. of the total discharge. A channel equal to one-fourth of the mean daily flow would carry off nearly 17 per cent. of that quantity; while a channel, with a capacity equal to one-eighth the mean discharge, would convey 10 per cent., and one equal to one-twentieth would yield very nearly 5 per cent., or about as much as its maximum discharge.

The formula used by the Author in establishing the economical size of channel is

$$\phi = \left(\frac{R}{12} \times \frac{D}{4}\right)$$

where ϕ = the equivalent in inches of rain that would be carried down by a channel equal to the mean daily discharge of the stream; R = the rainfall during any year, and D = the discharge for such year in inches of rain. For any channel of less capacity than the average daily discharge, the formula becomes

$$\phi = c\left(\frac{R}{12} + \frac{D}{4}\right),$$

where ϕ = quantity conveyed by channels of various sizes, c being the coefficient varying with the size of channel. The value of c

for a conduit equal to the daily average of the stream feeding the conduit is 1·00. (Appendix, Table XVI.)

Where the proportion between R and D is known, as is frequently the case, the formula becomes

$$\phi = \frac{c\,(1 + 3\,n)\,R}{12},$$

where $n\,R$ = discharge D; ϕ and R as above; c being the coefficient varying with the size of the conduit.

Table XVII. shows the quantity of water which conduits of various sizes would have been capable of carrying off if fed by the Nepean and Cataract rivers.

The interval to which direct reference is made in this Paper only extends from 1869 to 1876; but the whole period during which gaugings have been taken has been used for correcting formulas, or for the purpose of comparison, the mean results for the restricted period agreeing with those for the whole period from 1869 to the present time.

The formulas and conclusions are intended in the first place to illustrate the conditions of flow in small mountain streams in New South Wales; but the circumstances connected with the Australian climate are not, as is often assumed, very different from those which obtain in other parts of the world, and it is therefore probable that the experience acquired in New South Wales may be of use in similar circumstances elsewhere.

The Author is indebted to Mr. E. O. Moriarty, M. Inst. C.E., for the records of the Harbours and Rivers Department, New South Wales, the information obtained from which has been used to a considerable extent in this Paper.

The Paper is illustrated by a map and several diagrams, from which Plate 7 has been engraved.

[APPENDICES.

APPENDICES.

TABLE I.—RAINFALL at the CATARACT and NEPEAN RIVERS.

Year.	Cataract River.	Nepean River.	Proportion of Nepean to Cataract Rainfall.
	Inches.	Inches.	Per cent.
1869	14·35[1]	12·77[1]	82·00
1870	64·16	64·01	99·70
1871	53·70	43·36	80·70
1872	40·23	34·37	85·40
1873	75·08	59·49	76·98
1874	53·73	40·60	75·75
1875	54·36	41·28	75·90
1876	45·77	36·27	79·20
Mean	56·35	44·02	82·50

[1] Six months only.

TABLE II.—SHOWING DEPTH of RAIN in INCHES, and DISCHARGE in MILLION GALLONS, of the CATARACT and NEPEAN RIVERS.

Month.	1869.				1870.			
	Rainfall.		Discharge.		Rainfall.		Discharge.	
	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.
January .	..	..	..	..	2·78	2·81	395	1,258
February .	..	..	..	..	1·55	1·65	600	648
March . .	..	..	..	..	17·62	15·46	9,201	42,882
April . .	..	..	..	..	6·79	9·33	8,203	44,394
May . .	..	..	..	..	9·28	6·87	6,067	31,452
June . .	..	..	..	..	1·57	1·72	4,467	8,234
July . .	3·10	2·43	2,349	2,315	2·35	2·25	1,978	7,814
August .	0·62	0·46	539	839	2·31	1·25	1,677	3,408
September.	1·60	1·51	450	760	1·11	1·23	625	1,517
October .	2·07	2·69	345	745	4·65	5·55	2,831	10,290
November.	5·28	4·72	723	2,275	6·35	8·09	4,781	19,021
December .	1·68	0·96	142	626	7·80	7·80	3,070	8,970
Totals .	14·35	12·77	4,548	7,560	64·16	64·01	43,895	179,888

TABLE II. (*continued*).—SHOWING DEPTH of RAIN in INCHES, and DISCHARGE in MILLION GALLONS, of the CATARACT and NEPEAN RIVERS.

Month.	1871.				1872.			
	Rainfall.		Discharge.		Rainfall.		Discharge.	
	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.
January .	5·62	5·59	2,737	8,151	6·13	5·22	1,441	1,498
February .	4·45	4·41	2,900	8,700	3·62	3·45	565	1,655
March . .	6·18	3·82	1,819	6,587	6·23	4·37	1,234	1,467
April . .	10·98	7·82	4,650	17,506	1·20	0·88	421	1,120
May . .	10·11	10·09	7,190	30,641	1·15	0·84	223	499
June . .	3·96	2·28	4,764	8,657	0·33	0·27	141	342
July . .	0·41	0·43	1,624	2,857	1·35	1·17	133	417
August .	0·24	0·10	235	991	0·98	1·02	85	539
September.	0·78	0·74	137	541	1·53	0·99	81	286
October .	6·11	3·91	565	1,501	4·90	4·06	1,283	4,190
November.	2·53	2·62	207	865	6·25	7·06	2,065	7,737
December.	2·33	1·55	91	350	6·56	5·04	3,012	8,438
Totals .	53·70	43·36	26,919	87,347	40·23	34·37	10,684	28,188

Month.	1873.				1874.			
	Rainfall.		Discharge.		Rainfall.		Discharge.	
	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.
January .	5·39	4·00	2,004	7,187	3·77	2·75	1,107	1,313
February .	22·43	19·78	6,265	45,404	13·28	9·62	4,100	33,592
March . .	2·18	1·47	2,372	7,791	6·17	5·31	3,366	4,618
April . .	8·10	5·74	3,682	5,948	4·04	4·15	1,696	3,205
May . .	0·36	0·38	501	1,240	4·10	3·29	2,515	4,559
June . .	14·13	10·28	7,307	28,413	6·44	4·68	4,610	5,341
July . .	5·99	4·20	3,957	7,529	7·60	5·44	5,744	8,307
August .	2·38	1·52	2,376	4,086	1·88	1·16	3,430	7,267
September.	1·01	0·63	958	1,410	1·37	1·15	306	888
October .	2·01	1·38	492	668	2·96	2·56	420	1,375
November.	6·07	5·00	1,100	3,815	2·40	2·08	328	457
December.	5·03	3·11	1,618	3,344	0·37	0·31	66	254
Totals .	75·08	57·49	32,632	116,835	54·38	42·50	27,688	71,176

TABLE II. (*continued*).—SHOWING DEPTH of RAIN in INCHES, and DISCHARGE in MILLION GALLONS, of the CATARACT and NEPEAN RIVERS.

Month.	1875.				1876.			
	Rainfall.		Discharge.		Rainfall.		Discharge.	
	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.
January .	1·74	1·71	21	174	3·39	2·86	11	386
February .	10·21	9·91	1,547	2,978	2·67	2·02	12	221
March . .	10·52	5·77	5,889	13,387	0·93	0·52	19	183
April . .	6·10	3·58	3,234	7,124	4·95	2·66	88	670
May . .	8·59	7·05	4,634	15,114	6·26	5·66	2,007	3,281
June . .	8·28	6·25	3,780	12,974	3·10	2·34	2,772	1,197
July . .	0·66	0·55	832	2,920	..	..	..	..
August .	0·52	0·52	526	1,023	..	..	..	..
September.	1·31	0·89	139	410	..	..	..	..
October .	3·34	1·78	83	356	..	..	..	..
November.	1·17	0·87	17	187	..	..	..	..
December.	1·92	2·40	8	106	..	..	..	..
Totals .	54·36	41·28	20,710	56,753	21·30	16·06	4,909	5,938

TABLE III.—SHOWING PROPORTION of RAINFALL DISCHARGED by EACH RIVER.

Year.	Rainfall.		Discharges in Inches of Rain.		Percentage of Rain Discharged.		Proportion of Nepean Rain to Cataract Rain.	Proportion of Nepean Discharge to Cataract Discharge.
	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.		
1869	14·35	12·77	4·48	1·82	31·22	14·30	89·00	40·80[1]
1870	64·16	64·01	43·30	43·66	67·48	68·20	99·70	100·80
1871	53·70	43·36	26·54	21·23	49·42	49·00	80·80	80·00
1872	40·23	34·37	10·53	6·85	26·17	19·93	85·40	65·00
1873	75·08	57·49	32·58	28·40	43·38	49·40	76·98	88·71
1874	54·38	42·50	27·33	17·30	50·25	40·70	78·15	63·30
1875	54·36	41·28	20·42	13·79	37·60	33·40	75·90	67·50
1876	21·30	16·06	4·84	1·44	22·74	9·00	75·40	29·75[1]
Average	53·99	44·28	24·14	19·54	44·70	44·10	82·00	81·00

[1] Six months.

TABLE IV.—NEPEAN RIVER.

(a) Rainfall.	(b) Discharge.	(c) Proportion of Rainfall to Discharge.
1870	1870	1870
1873	1873	1873
1871	1871	1871
1874	1874	1874
1875	1875	1875
1872	1872	1872

TABLE V.—CATARACT RIVER.

(a) Rainfall.	(b) Discharge.	(c) Proportion of Rainfall to Discharge.
1873	1870	1870
1870	1873	1874
1874[1]	1874	1871
1875[1]	1871	1873
1871[1]	1875	1875
1872	1872	1872

[1] Nearly equal.

TABLE VI.—FRESHETS, CATARACT RIVER.

Length of Freshet.	Rainfall.		Discharge.	
	Total.	Per Day.	Equivalent to Rain.	Proportion of Total Rain.
Days.	Inches.	Inch.	Inches.	Per cent.
306	100·83	0·33$_v$	67·50	67·0
92	13·66	0·15$_x$	3·24	23·7
14	4·90	0·35$_v$	1·19	24·3
124	40·99	0·33$_v$	15·33	37·4
42	8·05	0·19$_x$	3·97	49·3
104	23·32	0·224$_x$	14·22	69·9
56	10·02	0·18$_x$	2·67	26·6
261	45·35	0·19$_x$	26·31	58·0
163	43·86	0·27$_v$	19·45	44·3

TABLE VII.—SERIES *v*.

Length of Freshet.	Proportion Flowing Down Streams.
Days.	Per cent.
306	67·0
163	44·3
124	37·4
14	24·3

TABLE VIII.—SERIES *x*.

Length of Freshet.	Proportion Flowing Down Streams.
Days.	Per cent.
261	58·0
104	69·9
92	23·7
56	26·6
42	49·3

Table IX.—Freshets, Nepean River.

Length of Freshet.	Rainfall.		Discharge.	
	Total.	Per Day.	Equivalent of Rain.	Proportion of Total Rain.
Days.	Inches.	Inch.	Inches.	Per cent.
306	93·56	0·30$_y$	63·40	67·8
92	11·76	0·13$_z$	1·27	10·9
14	4·06	0·29$_y$	0·94	23·1
124	33·14	0·27$_y$	18·43	55·6
42	5·69	0·14$_z$	1·65	29·0
104	16·56	0·16$_z$	9·95	60·0
56	7·28	0·13$_z$	1·72	23·6
261	35·12	0·134$_z$	16·67	47·5
163	32·70	0·20$_z$	10·14	31·0

Table X.—Series *y*.

Length of Freshet.	Proportion of Flow.
Days.	Per cent.
306	67·8
124	55·6
14	23·1

Table XI.—Series *z*.

Length of Freshet.	Proportion of Flow.
Days.	Per cent.
261	47·5
163	31·0
104	60·0
92	10·9
56	23·6
42	29·0

Table XII.—Values of Coefficient (*t*).

Inches.
For 350 days $t = 2{\cdot}6$
,, 300 ,, $t = 2{\cdot}5$
,, 250 ,, $t = 2{\cdot}4$
,, 200 ,, $t = 2{\cdot}2$
,, 150 ,, $t = 2{\cdot}1$
,, 100 ,, $t = 2{\cdot}0$
,, 50 ,, $t = 1{\cdot}9$
,, 25 ,, $t = 1{\cdot}8$

Table XIII.—Values of Coefficient (*c*).

Inch. Inch.
The values of *c* are, for 0·40 = 0·95
,, ,, ,, 0·35 = 0·90
,, ,, ,, 0·30 = 0·85
,, ,, ,, 0·25 = 0·80
,, ,, ,, 0·20 = 0·75
,, ,, ,, 0·15 = 0·70
,, ,, ,, 0·10 = 0·65

TABLE XIV.—CATARACT RIVER.

Length of Low Discharge.	Rainfall.		Discharge.	
	Total.	Per Day.	Equivalent of Rain.	Proportion to Total Rain.
Days.	Inches.	Inch.	Inches.	Per cent.
190	15·44	0·081	2·72	17·6
194	14·72	0·076	1·78	12·1
162	6·60	0·040	0·80	12·1
34	1·60	0·048	0·17	10·6
17	0·27	0·016	0·14	51·9
13	0·26	0·020	0·13	36·1
54	3·28	0·060	0·67	20·4
20	2·07	0·104	0·23	11·1
147	8·73	0·059	1·01	11·6
287	20·67	0·090	1·08	5·2

TABLE XV.—NEPEAN RIVER.

Length of Low Discharge.	Rainfall.		Discharge.	
	Total.	Per Day.	Equivalent of Rain.	Proportion to Total Rain.
Days.	Inches.	Inch.	Inch.	Per cent.
190	14·74	0·077	1·61	11·1
194	10·63	0·055	1·18	11·1
162	5·21	0·032	0·55	10·4
34	1·93	0·057	0·19	9·8
17	0·23	0·013	0·08	34·8
13	0·38	0·030	0·09	23·7
54	2·38	0·052	0·38	12·3
20	1·42	0·061	0·11	9·7
147	7·67	0·052	0·68	8·9
287	14·93	0·052	1·04	7·0

TABLE XVI.

For conduit equal to 75 per cent. $c = 0{\cdot}835$
" " 50 " $c = 0{\cdot}634$
" " 25 " $c = 0{\cdot}380$
" " 12½ " $c = 0{\cdot}253$
" " 7½ " $= 0{\cdot}160$
" " 5 " $= 0{\cdot}118$

TABLE XVII.—DISCHARGE of CHANNELS of VARIOUS SIZES.

Year.	Channel equal in Capacity to—				
	Mean Daily Discharge.	$\frac{1}{2}$ Mean Daily Discharge.	$\frac{1}{4}$ Mean Daily Discharge.	$\frac{1}{8}$ Mean Daily Discharge.	$\frac{1}{20}$ Mean Daily Discharge.
	Percentage of water that would be carried off during the year.				
	CATARACT.				
1870	62·70	37·00	21·25	11·63	4·90
1871	41·00	25·50	16·25	10·00	4·85
1872	19·60	14·25	10·75	7·75	4·50
1873	47·20	29·20	18·50	11·25	5·00
1874	62·70	37·00	21·25	11·63	4·90
1875	41·00	25·50	16·25	10·00	4·85
	NEPEAN.				
1870	59·00	37·25	21·33	11·37	4·83
1871	36·80	26·85	16·70	10·87	4·94
1872	18·00	14·00	10·25	7·70	4·90
1873	38·10	28·70	18·40	11·25	5·00
1874	59·00	37·25	21·33	11·25	4·83
1875	36·80	26·85	17·20	10·87	4·98

(*Paper No. 1949.*)

"Timaru Water-Supply."

By Arthur Dudley Dobson, M. Inst. C.E.

The town of Timaru, on the east coast of the Middle Island of New Zealand, faces the east, and is situated on downs which end in cliffs about 30 feet high abutting on the sea-beach.

The principal part of the town is about 30 feet above high-water mark, the highest point being about 80 feet; while a number of the business premises, the railway station, and various mills, are near the sea-beach. The downs rise westward, attaining their greatest altitude in Mount Horrible, 800 feet high, about 10 miles from the sea. To the westward of Mount Horrible is a deep valley, which cuts off all connection between the downs and the high lands at the back; the downs are from 6 to 7 miles wide, and are intersected by numerous deep gullies. To the northward lies the south end of the Canterbury Plains, and to the southward the River Pareora.

The downs consist of a stratum of loess 30 feet thick, which rests upon a sheet of dolerite, varying from a few feet to 20 feet in thickness. The dolerite forms the summit of Mount Horrible, and reaches the sea-level at Timaru. Below the dolerite, beds of gravel occur, and below the gravel tertiary limestones and sandstones. The loess is very hard and impervious to water. Rain soaks in but a very little distance, the greater part running rapidly off by the gullies into the sea. No natural ponds or pools exist on the downs, and water is only found in the gullies in winter. In this part of New Zealand the rainfall is small; for months at a stretch the weather is dry, so that Timaru was badly off for water.

In one or two cases wells had been sunk into the gravel which had previously been stream beds on the dolerite, before the deposition of the loess. These gave a small quantity of good water. Public wells were sunk below the dolerite into the underlying gravels; but the supply from these was limited in summer, and was always hard and slightly brackish. This appears to be a characteristic of all the water coming out below the dolerite. In the construction of the race several springs were struck, just below the dolerite, the water from which tasted exactly like that in the Timaru wells.

All the better houses were furnished with underground tanks for storing rain; these generally contained from 3,000 to 5,000 gallons, and were made by digging a circular well in the loess, trimming the sides smooth, and then plastering them with a thin coat of cement-mortar, the top being covered either with wood or a thin dome of concrete. The rain was led from the roofs of the houses by pipes into a sump filled with shingle before it ran into the tank, and was thus relieved of some of its impurities. The water was pumped out for use; but in spite of all precautions, organic matter accumulated in the tanks; rats, mice, and worms got in frequently. When the tanks and wells failed, water had to be carted from a great distance; so every one economised water to the utmost in the summer months. An efficient water-supply was therefore a question always before the inhabitants of Timaru. Numerous projects were mooted; but from the first it was seen that the River Pareora afforded the best means of supply, by bringing the water round the southern slopes of the downs to some point at the back of the town, from which it could be delivered by gravitation.

The first steps were taken in 1870, when levels were obtained from the Pareora through the Crown lands nearly to Timaru, and reservations of land were made on this line. In 1873 a contract was entered into with Mr. James Fraser, to bring the water into the town and to maintain the works for a few months for the sum of £3,500. This was done, and the water from the Pareora flowed through the gullies in the town; but the work was effected in a temporary and perfunctory way, and as soon as the contractor's term of maintenance had expired, it was allowed to fall out of repair, as the expense of maintenance would soon have exceeded the cost of construction.

After this a site for a reservoir was selected on the downs, 2 miles from the town boundary, and 220 feet above sea-level; here a rectangular oblong reservoir with well battered slopes was constructed, capable of containing 5,385,000 gallons, at a cost of £6,500. The whole of the sides and bottom were pitched with blue stone pitchers, 9 inches long, lying on a bed 9 inches thick of broken metal. A tunnel about 100 feet long was made from the end next the town, at the extremity of which a shaft rose to the surface; the tunnel and shaft were brick-lined. The bricks were set in lime mortar; there was no puddle behind them, and throughout the tunnel a 6-inch space was left at the back of the bricks.

Nothing further was done until 1876, when the late Mr. Henry Wrigg was appointed engineer. He built a concrete dam in the Pareora, made a survey of the old race, took levels, and prepared a plan of the town reticulation on which tenders were invited for the requisite plant. This arrived in 1879, but some delay occurred in raising a loan, and the year 1880 was far advanced before the necessary funds were procured. In the meanwhile further work was stopped and Mr. Wrigg died.

In September 1880 the firm of Messrs. Edward Dobson and Son was appointed Waterworks Engineers, and the Author commenced the surveys necessary for getting out the contracts for the race. Much trouble was experienced in endeavouring to utilize the existing work and plant to the best advantage. No plan was to be found showing in detail the proposed reticulation except a very general one, and this did not in the least correspond with the plant provided. A quantity of 2½-inch pipes had been provided, with junctions 14 inches, 13, and 12 inches long, by 2½ inches in diameter. As the Author considered 3 inches the smallest diameter of pipe which should be used for mains, on which fire-plugs were to be placed, the reticulation had to be re-planned. Pipes 4 inches in diameter were substituted for 2½-inch pipes, and schedules of the requisite straight pipes and special castings were prepared. The former of these, together with all the wrought-iron work required for flumes for the race, were imported from Messrs. Laidlaw, Son, and Caine, of Glasgow. The latter were provided by Messrs. Sparrow and Co., of Dunedin. Tenders were also invited for the supply of 18-inch stoneware-pipes, and for the supply of valves and fire-plugs; the latter were made in Dunedin.

As soon as the survey of the race had been completed, tenders were invited for its construction. Where the ground was solid, watertight, and not too sideling, an open race was cut, 18 inches wide at the bottom, 4 feet wide at the top, and 2 feet 6 inches deep. In loose rocky ground, a concrete culvert was formed, 2 feet wide and 2 feet 6 inches deep, the concrete being 12 inches thick on the sides, 6 inches on the bottom, and with all the interior face plastered with cement mortar. In steep sideling ground, subject to slips, a road was cut back from 20 to 30 feet into the solid ground; and an 18-inch stoneware pipe was laid in a trench on the inside of this. Where the ground was steep and leaky, although pretty solid, the stoneware-pipe was deposited in a trench, the centre of which was never less than 5 feet from the edge of the solid ground. These pipes were all carefully bedded before being jointed; when in place the joint was set in cement mortar. The pipe was laid at as steep a gradient as the race admitted, but nowhere less than 5 feet per mile. In consequence of the way in which the ground had been trenched by the original race, it was considered advisable to adhere to the old line as much as possible, with the result that the grades varied from 2 feet 6 inches to 6 feet per mile. In order to avoid structures, the old race had contoured round all spurs and gullies, with very few exceptions. It was found inexpedient to do this when constructing a permanent work, and the gullies were therefore crossed either by flumes or by siphons. Spurs were traversed by tunnels and cuttings, by which means the length of race between the dam and reservoir was reduced from 27 to 17¼ miles. As the old route was mostly followed, where a flume, siphon, or tunnel cut off a long bend, a great fall was thrown into a short length; and by this means flumes and siphons of small size and little cost were enabled to carry a large volume of water. In a few instances where the flumes are short, and only a short distance has been saved, they have but little fall; but in all cases where these are of any length the fall varies from 10 to 87 feet per mile. In the case of the three siphons the fall per mile is as follows: 14-inch pipe, 25·97 feet; 12-inch pipe, 43 feet; 10-inch pipe, 96·7 feet. The tunnels also have ample fall, so that the carrying capacity of the race is double the present requirements so far as regards costly works. The race is intended to supply 1,500,000 gallons in twenty-four hours. As the works have been carried out, the capacity is governed by the 18-inch stoneware pipes; by duplicating these and making a few inexpensive additions at the siphon heads, and at two or three of the flatter flumes, the race would carry 3,000,000 gallons in twenty-four hours, and the cost of thus doubling the volume of water-supply would not exceed £5,000.

The wrought-iron work of the flumes comprises the plates, angle-iron braces, ties and rivets, all of which were imported from Scotland. The cast-iron sockets in which they rest were cast in Timaru. When riveted up they form a perfectly rigid girder. The ends lie in concrete blocks on rubber packing, and are perfectly tight. The flumes are supported on wooden trestles made of heart of totara, being further stiffened, where liable to injury from exposure to high winds, by the introduction of concrete piers. The short trestles are bolted to sole-plates bedded in the ground, and the longer ones are bolted to concrete foundations. They are all exceedingly rigid, and show no signs of movement in the heaviest gales.

The lengths of different classes of work along the aqueduct are as follow:—

	M.	Ch.	Lks.
Concrete-lined channel		30	00
Wrought-iron flumes		40	39
Siphons, cast-iron pipes		32	16
Tunnels		22	00
Stoneware pipe	1	61	50
Stone culverts under road-crossings		15	00
Wooden flumes in short lengths		11	04
Open channel	13	50	00
Total	17	22	09

It had been intended to take the water through an opening in the dam of concrete in the Pareora river into the race, and a 3-feet culvert was placed in the bottom of the wall, which, being opened occasionally, was to scour away the shingle and sand accumulated behind the dam. A side stream came in just at the entrance of the race, the shingle from which not only blocked the entrance but became piled up over the wing-walls. The engineers deemed it advisable to alter the method of offtake. A perforated cast-iron pipe was placed on the top of the dam, with a heavy stone coping on the lower side. The top of the coping was 6 inches higher than the top of the pipe, which was thus always kept full of water. All flood-water flows over the pipe, and when the river-bed behind the dam is choked, the shingle passes over the pipe without interfering with the supply to the race. To prevent scour from the water passing over the dam, a cushion-wall was built to back up the water on the lower side of the dam.

The old brick-lined tunnel was uncovered, its inner end being secured by a concrete block surrounding the 18-inch outlet-pipe. The top and sides of the tunnel were covered with concrete, and the trench was filled in with earth in 18-inch layers, well wetted and rammed. The outlet-pipe is fitted with a valve, from whence the water flows in a concrete culvert to the pipe-head, where it passes through three wire-gauge strainers into the main leading to Timaru. Concrete channels are arranged so that the water may be led into the pipe-head, direct from the race. The works were carried out in this way in the first instance, as there was no pipe on the ground of sufficient size to lay from the reservoir to the point of the spur, where the pipe-head stands, and provision had to be made for scouring the reservoir.

Plans have subsequently been prepared for connecting the mains directly with the reservoir. The water will pass from a valve-well to a straining-well, and thence into the town mains. It would have been undesirable to have adopted this expedient had there been any scarcity of water; but as the town did not need one-tenth of the water daily running into the reservoir, it was considered sufficient for the time, and would be used as a scour-channel and by-pass eventually.

The water is conveyed to the town boundary in a pipe 14 inches in diameter. Unless frequently moved, the lower valve was apt to become set by the great pressure on the lower ring. It was therefore decided to take off the top, and to screw on a cast-iron cover fitted with three spring high-pressure steam valves 4 inches in diameter. These are adjustable by nuts, and are screwed down to blow off at a pressure of 80 lbs. per square inch; they have been found to work very well.

The 14-inch main is carried a little way into the town boundary, and, after the first few junctions, is reduced rapidly to 13 inches, 12 inches, and 11 inches in diameter. The 11-inch main runs through a great part of the principal streets of the town, thus ensuring an ample supply of water for fire purposes where it is most needed. The pipes then branch off into 10, 8, 7, 6, 4, and 3-inch pipes; 2½-inch pipes are laid down as riders on the opposite side of the street to that on which the mains run, for domestic services only. A large air-vessel connected with a 10-inch main relieves the mains of any sudden shock in the town.

The works, which were well done, were let in thirty-three small contracts, with a view to their being taken by parties of working men. Although this course entailed a great deal of office-work and supervision, it was found to answer. In all cases the contracts were taken below the engineer's estimates, the total difference between the cost and estimate being £4,000. It is only fair to add that many of the contracts were effected at so low a rate that the men did not make wages at them. The total cost of all the works executed under the Author's supervision, including £900 for the purchase of land, survey, and legal charges, was £42,000. On the completion of the work, there remained of the money raised on the loan £10,200. This money is now being expended in extending the waterworks beyond the boundaries of the borough. Prior to the Author's firm being appointed, £17,480 had been expended; of this sum, £5,700 had been wasted in useless surveys and in works which had failed; the difference, £11,780, was represented by the dam, reservoir, and plant for the town reticulation. The greater part of this money had been provided by the late provincial government. The borough then raised a loan of £60,000, of which £7,200 went to cover previous expenditure; a sum of £42,000 was spent by the Author's firm, and the balance, £11,200, was represented by £10,200 in the bank, and £1,000 worth of plant. The £400 excess shown here, was the interest on the money lying at fixed deposit during the execution of the work.

The town reticulation was filled with water from the Pareora in November 1881, and by the end of December the operations were completed. Progress was considerably delayed by the non-arrival of iron from England when expected.

The population of the borough is about four thousand, and the suburbs outside the boundary contain about four thousand more.

The annual interest on the loan of £60,000 is £4,200. To meet this, there is a special rate of 1*s.* in the £, and 1*s.* in the £ for use of water. A good deal of water is being sold for power, gardens, railway and shipping, at special charges; and there is no doubt that when the mains are extended throughout the suburbs, the receipts will be such as will enable the rates within the borough to be materially lowered.

To illustrate the work, complete copies of the following contracts have been supplied with the Paper[1]:—

A	Contract.	1	Headworks.
B	„	4–7	Stoneware pipes.
C	„	8	Service-reservoir.
D	„	11	Siphons.
E	„	14	Russell's tunnel.
F	„	15	14-inch main.
G	„	18	Fencing material.
H	„	21	Special castings.
I	„	23	Hydrants, valves and surface-boxes.
J	„	25	Iron flumes.
K	„	27–28	Town reticulation.
L	„	31	Galvanised iron service-pipes and brass work.
M	„		General character of works on race.
N	„	35	Straining-well and by-pass.
O	„		General plan.

There is also a sheet showing the manner in which the race sections were prepared for contract, and the different classes of work used on the race.

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[1] These have been placed in the Library for reference, with a copy of the contract drawings.

(*Paper No. 1952.*)

"Reconstruction of the Bhim Tal Dam, Kumaon, N. W. P., India."

By Francis Henry Ashhurst, Assoc. M. Inst. C.E.

The irrigation-canals in the Bhābur, or waterless tract of country at the foot of the Kumaon hills, between the latter and the Terai district, are fed by water from the main rivers as they debouch from the hills.[1]

During the dry months of the cold and hot seasons, the water in the Gola, one of the most important of these rivers, becomes very low, and the supply in the canal at the headworks, near Haldwani, the chief place of the district, would often be scanty if it were not supplemented by surplus water from the large reservoirs in the hills, formed by damming up one or two of the natural lakes in the neighbourhood of Naini Tal.

The most important of these reservoirs is Bhim Tal, about 10 miles east of Naini Tal, and the same distance north of the headworks of the canals. This lake is about 4,500 feet above sea-level, 3,000 feet above the bed of the Gola river, near Haldwani, and when full nearly 6,000 feet in its greatest length, and from 1,000 to 1,500 feet in breadth. Its greatest depth below the natural water-surface, or exclusive of the 46 feet of water dammed up artificially, is about 90 feet.

The first dam across its outlet, which was used for irrigation purposes, was constructed by Captain (now Sir Henry) Ramsay, K.C.S.I., Commissioner of Kumaon, about thirty years ago. But its height was only sufficient to store up some 16 feet depth of water above the ordinary level of the lake. Twenty years later a much larger dam was made, by which a supply of about 32 feet in depth over the outlet sill, equivalent to nearly 125,000,000 cubic feet of water, was rendered available for irrigation in the dry months, independent of the perennial springs by which the lake is constantly fed. Owing, however, to the weak design and construction of this dam, namely, a thin masonry wall, nearly 40 feet high at the outlet, and only 4 feet thick at the top and

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[1] Minutes of Proceedings Inst. C.E., vol. xxxv., p. 144.

10 feet at bottom, in the middle of a huge earthen dam 25 feet wide at the top, fears of failure were constantly entertained when any sudden floods occurred. But with careful watching and timely repairs it lasted, in spite of constant leakage, for more than ten years, and fully repaid its original cost, although severely tried in the storm of September, 1880, which caused the disastrous landslip at Naini Tal. In August, 1882, however, after another severe trial from heavy storms, it gave way at the main outlet. The lake was nearly full at the time, but no great damage was done in the ravines below, chiefly owing to large blocks of masonry from the hearting and main outlet of the dam falling into and blocking up the escape channels, so that the water ran out comparatively slowly during a whole day.

As the prosperity of the Bhābur cultivation on the Haldwani side depends largely on the water supply from this lake, Sir Henry Ramsay determined to substitute a dam entirely of masonry or concrete. The site of the dam recently destroyed had been much shaken near the outlet by the rush of water and falling blocks of masonry, and the rock foundation at this point being considerably undermined, it became necessary to construct the new dam nearer the lake (Plate 8, Figs. 1 and 2). Here a foundation of sound rock was obtainable for the highest part of the new wall. In order to utilize as much of the roadway of the old dam as possible, and of a large three-arch storm-overflow recently constructed, the new dam was designed nearly in the form of a semi-circle 500 feet long, with its convex side towards the lake. As the new dam in its highest part was to be nearly 50 feet from base to roadway, great care was taken in preparing the foundations across the outlet. This outlet had been scoured out 10 to 15 feet below its former level at the destruction of the late dam, and in consequence it became possible to draw off for irrigation a much greater volume of water than before, namely, about 150,000,000 cubic feet when the lake is full, or sufficient for three weeks' supply in the canals, independent of all other sources, and this without raising the level of the top of the dam above that of the old road.

The section of the new dam was designed in accordance with Professor Rankine's general section for masonry dams,[1] which shows a width of rather over 35 feet at the base for 50 feet in height, and a minimum width of 10 feet at top was assumed as

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[1] The Roorkee Treatise of Civil Engineering in India, vol. i., 3rd edition, p. 436.

necessary for the roadway which had to be carried over the dam. The maximum width of base adopted at the highest place was 36 feet, but as the wing-walls necessary for the well and sluices of the main irrigation-outlet (Figs. 3 and 4) had also to be arranged at this point, and were bonded into the main dam so as to make one solid mass, the full width of dam at its highest point exceeds 50 feet, being much more than is required by theory.

In the dam lately destroyed there had been two outlets for irrigation close together, at the same level, each 4 feet wide and 12 feet high, at the highest part of the dam; and also up to September, 1880, two storm-overflow openings 10 feet from the top of the dam, each 8 feet wide. In the great storm of September, 1880, these latter proved insufficient, and the dam was almost destroyed. With both the irrigation-outlets and the storm-overflow open the water in the lake rose to within a few inches of the top of the dam. As it was, the two-arch storm-outlet was practically destroyed, and a new overflow of three arches of 8 feet each was constructed on the opposite or left bank in 1881 (Fig. 1), and the old escape was closed. This new escape, as already stated, has been worked into the present design, and an additional storm-outlet of two 8-feet arches has also been given on the right bank, so that the irrigation-outlets need never be used as escapes in floods, and thus a source of danger to the dam will be removed, and the inconvenience of leaving the sluice-gates open till the end of the rains, and running the risk of the lake failing to be filled, will be avoided. In the old dam the fall of over 30 feet from the lake when full into the irrigation-wells beneath caused a dangerous vibration in the masonry of the main outlet, and it was therefore arranged in the new dam that the two openings for irrigation should be some distance apart, and at different levels. By this contrivance the fall into either of the irrigation-wells would never exceed 18 feet, of which the lower 3 or 4 feet would be a well or water-cushion to receive the shock of the descending water. The sluices are constructed of neatly-dressed sal wood (*Shorea robusta*) planks, 6 inches thick, placed with close joints in rows 2 feet apart; between the rows of planks well-puddled clay is rammed when the irrigation-outlets are being closed. The planks work in grooves 7 inches wide, and the masonry at these places is set in Portland cement mortar. For the main irrigation-outlet, where a depth of 46 feet of water is dammed up, there are, up to 30 feet depth of water over the sill, three rows of planks, the outer row nearest the lake being 10 feet long, with a bearing on the walls of

3 feet at each end. For the intermediate irrigation-outlet, where the maximum depth of water is 28 feet, only two rows of planks, 5 feet long, working in similar grooves have been arranged. These planks are fitted with iron eyelets, and are put into position at the commencement of the rains early in June, as soon as the lake begins to rise, and the puddled clay is carefully prepared and rammed between the rows to prevent leakage.

Towards the end of the rains, in September, when the lake is full, the overflow escapes by the five arches of the two storm-outlets, 10½ feet below the top of the dam; but when the rains are nearly over these storm-outlets are also closed with planks and clay, and the water in the lake is allowed to rise without hindrance. The maximum depth that can be stored is 46½ feet over the sill of the main irrigation-outlet, or 6 inches below the top of the dam, but it will very seldom be necessary to store a greater depth than 40 feet. When water is required for irrigation in the cold weather, as many planks as may be necessary are lifted by ropes fitted with iron hooks at the intermediate or upper irrigation-outlet; and when during the hot weather the level of the water in the lake has been reduced to 28½ feet below the top of the dam, the main or lower irrigation-outlet comes into use until all the water available for irrigation has been run off. This rather primitive arrangement for letting off the water was adopted in preference to the ordinary inlet tower with iron sluices, as the native establishment in charge of the dam would not be capable of controlling the machinery, or of repairing anything that might go wrong, and the regularity of discharge was of no importance.

At first it was proposed to construct the new dam entirely of concrete; but there would have been great difficulty in arranging a satisfactory framework of face-boards to support the sides during the ramming and the setting of the concrete, and as plenty of good stone was available, the outer faces were built of uncoursed rubble masonry, varying from 5 feet thick at the bottom to 2½ feet at the top (Fig. 5); and concrete was rammed between these face-walls, which are tied together at all openings. By this arrangement also all available labour was fully utilized by employing the ordinary Kumaon masons on the walling, and Dotyal coolies from Nepaul on the concrete hearting. In the winter the total daily number of workmen never exceeded three hundred; but in the summer often as many as four hundred and fifty were engaged.

During September and October, 1882, the design for a new dam was matured, and contracts for the collection of materials were given. Excavation of the foundation was put in hand early in

November, 1882, and concrete and masonry work was commenced early in December. Considerable difficulty was experienced in laying the foundations in the deepest part, owing to the constant discharge from the lake, and from independent springs. A deep drain was therefore cut on one side of the centre-line, and the invert of the lowest irrigation-outlet was completed up to 6 feet in height in cement mortar; and as soon as this portion of the work was sufficiently set, the drainage-water was made to pass through it, and the wall-foundation was completed across the full width of outlet. In this portion of the work the mortar used in both masonry and concrete was composed of 8 cubic feet of Portland cement, 16 cubic feet of slaked stone-lime, 8 cubic feet of finely-ground soorkhee (burnt clay), and 20 cubic feet of clean coarse sand, being 52 cubic feet per 100 cubic feet of finished work; but for all the rest of the work, except in a few important places, such as wet foundations, and sluice-grooves where the Portland-cement mortar was used, the proportions of mortar for 100 cubic feet of finished work were: 20 cubic feet of slaked stone lime, 10 cubic feet of finely-ground soorkhee (burnt clay), and 20 cubic feet of clean coarse sand. The building stone being of very irregular fracture, nearly as much mortar was used in the rubble masonry, including the face-pointing, as in concrete, the average quantity being about 50 cubic feet of dry mortar materials to 100 cubic feet of finished work.

The soorkhee and slaked lime were first finely ground together under edge-rollers, and then the sand, and finally the water was added. The concrete was mixed *in sitû*, layers of the broken quartzite stone were spread between the masonry face-walls about 4 to 6 inches thick, on which the prepared mortar was placed, and the whole was then well mixed with picks, and consolidated with 15-lb. cast-iron rammers.

The proportions of the concrete, exclusive of cement, were: 50 cubic feet of mortar as above, 100 cubic feet of quartzite, broken to 2-inch gauge, and 25 cubic feet of screenings of all kinds.

In the upper portion of the dam 6- to 9-inch cubes of rubble stone were thrown into the middle of the concrete wall, here and there, to economize mortar and hasten the work.

The masonry face-walls were always kept a foot or two above the concrete hearting, and were left rough and jagged on the inside faces to secure a good bond with the concrete. The cement was supplied by the Indian Portland Cement Company from Calcutta, in bags of two sizes. The larger bags of 2 cubic feet capacity, contained 186 lbs. of cement, and the smaller bags of 1 cubic foot capacity contained about 96 lbs. of cement. The loss in transit was very small, and as compared with English cement in barrels, from which, in India, the full quantity in a barrel is never obtainable, the Indian cement was on the whole much cheaper and quite as good. The cost per cubic foot of Indian Portland cement at Bhim Tal was about 4·75 rupees to 5 rupees, whereas English cement would have cost, allowing for loss, at least 6·75 rupees to 7 rupees. The total quantity of cement used was 2,000 cubic feet.

To check the great rush of water down the steep slope of the paved floors of the two storm-overflows, a series of wells with water-cushions from 3 to 7 feet deep were constructed at the ends of each of the escape floors (Figs. 6 and 7). The original well at the end of the three-arch overflow on the left bank had been completely destroyed when the late dam burst, and the upper part of the floor was left standing with a broken edge about 30 feet above the bed of the outlet of the lake. A 16-feet arch was accordingly built over the outlet at this place, through which the discharge from both irrigation-outlets, and also from the two-arch storm-overflow would pass, and over which the necessary wells to check the flood-discharge from the three-arch escape were constructed (Fig. 6). The final wells of the three-arch escape seem somewhat narrow; they would have been made a few feet wider had the ground been more favourable; but even in the greatest known rainfall the depth of flood water over the shortest sill, which is 10 feet long, cannot exceed 4½ feet.

The water from this three-arch escape finally joins the main channel about 40 feet below the 16-feet archway, where the ravine has been roughly paved with large boulders. The edges of all drop walls of wells were protected by nosings of sal wood, 9 inches and 6 inches, very securely fixed in the masonry; and most of the face-walls of wells, and some of the bottoms also were covered with thick sal planking to relieve the shock of water.

All the timber used in well-sleepers, nosings, sluice-planks, &c., was sal from the banks of the Gola river. This wood, which is admirably suited to the purpose, owing to its great density, when dressed and fixed in the work, cost about 1 rupee 8 annas per cubic foot free of royalty. The arch recesses, 8 feet high and 8 feet wide, above the irrigation-outlets in the main dam, were made partly for economy, but chiefly as places in which to store the sluice-planks as they are taken out one by one, when letting off the water for irrigation.

The total quantity of concrete and rubble masonry in the new dam, the two storm-overflows and wells, paved channels, &c., was

270,000 cubic feet, and the final cost, exclusive of supervision, was about 60,000 rupees, or at 2*s.* per rupee, £6,000.

	Rs.
270,000 cubic feet of rubble masonry and concrete (exclusive of Portland cement) at 16rs. 8as. per 100 cubic feet .	44,550
2,000 cubic feet of Indian Portland cement at 5rs. . .	10,000
1,400 cubic feet of sal timber at 1rs. 8as.	2,100
440,000 cubic feet of earthwork (soft rock and clay, excavation and filling) at 5rs. per 1000 cubic feet	2,200
Contingencies and ironwork in cramps, hooks, &c. . .	1,150
Total . . . . Rs.	60,000

The quantities of concrete and rubble masonry used were in the proportions of 1 to 2, the rates being 15 rupees and 17 rupees per 100 cubic feet respectively, or about 8*s.* and 9*s.* per cubic yard, exclusive of Portland cement, of which the details were as shown below :—

(1.) *Rubble Masonry.*

		Rs.
100	cubic feet of stone in wall at 3 rupees	3·00
20	„ slaked and screened stone lime at 4 annas each	5·00
10	„ finely pounded soorkhee at 15 rupees per 100 cubic feet	1·50
20	„ clean coarse lake sand at 3 rupees per 100 cubic feet	0·60
Water, &c.	. . . .	0·40
	Total materials.	10·50
Labour in mixing and carrying mortar	. . . . . .	1·50
Mason's labour	. . . .	5·00
	Total . . . . Rs.	17·00

(2.) *Concrete.*

		Rs.
125	cubic feet of broken stone and screenings at 3 rupees per 100 cubic feet	3·75
50	„ mortar, as above	7·10
Water, &c.	. . . .	0·65
	Total materials	11·50
Mixing and carrying mortar	. . . .	1·50
Consolidation	. . . .	2·00
	Total . . . . Rs.	15·00

The mortar used in exterior pointing of joints is included in the masonry rate, hence the large amount of mortar per 100 cubic feet.

The lime, which was rich, and required burnt clay to make it set in water, was burnt near Rānibag, at the foot of the hills, from boulders of blue limestone found in the bed of the river. Soorkhee was burnt on the spot, and sand was obtained from the bed of the lake. The broken stone for concrete was from quartzite lumps found in the neighbourhood, and broken to a 2-inch gauge.

All argillaceous earth excavated from the foundations was carefully stored, and afterwards replaced and tightly rammed against the faces of the new dam, as an additional precaution against leakage.

The accident to the old dam occurred on the 23rd of August, 1882, and the new dam was finished in August, 1883. The time occupied from the commencement of the new work to its completion was only nine months. The contracts for material were all arranged by Sir H. Ramsay, and the construction was carried out entirely by daily labour supervised by Mr. J. Docherty, who lived on the spot the whole time. No accident occurred. Owing to a sufficient winter rainfall, and to about 12 feet depth of water being impounded by a temporary dam, which became available for irrigation in March and April, no loss of crops occurred in the Bhābur, so that the destruction of the old dam may be looked upon without regret, it being confidently anticipated that the new dam will last as long as there may be any crops in the Bhābur lands to irrigate.

On the 29th of August, 1883, Sir Alfred Lyall, K.C.B., Lieutenant-Governor of the North Western Provinces and Oudh, accompanied by Colonel Mayne, R.E., Chief Engineer of the Province, made a careful inspection of the new dam.

At the Chief Engineer's suggestion a concrete wall, 4 feet wide, has been built across the upper 12 feet of the main irrigation opening in place of the innermost row of planking, as he considered the appearance of the left-hand wing-wall somewhat weak. But inasmuch as the lowest portion for 12 feet is built into solid rock, and as the corner between it and the main body of the dam is carefully filled up with dry walling and well-rammed clay, there can be little fear of accident from the highest possible water pressure which acts in various directions round it.

A great part of the left wing of the dam is founded on large boulders closely set in stiff clay. This foundation is practically as strong, or even stronger than the rock foundation of the right wing, as the boulder bed is from 15 to 20 feet below the natural surface, is thoroughly watertight, and has evidently been undisturbed for ages. A somewhat similar dam has been constructed near New York[1], but at a very great cost in comparison with that of the Bhim Tal Dam.

The Paper is accompanied by a sheet of diagrams, from which Plate 8 has been engraved.

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[1] Minutes of Proceedings Inst. C.E., vol. xl., p. 310.

(*Paper No. 1953.*)

"Pumping Hot Water."

By Henry James Coles, Assoc. M. Inst. C.E.

The depth from which hot water of a given temperature may be pumped can be theoretically deduced from the formula

$$\log. p = A - \frac{B}{t} - \frac{C}{t^2},$$

and the inverse of the above

$$\frac{1}{t} = \sqrt{\left(\frac{A - \log p}{C} + \frac{B^2}{4\,C^2}\right)} - \frac{B}{2\,C}$$

in which p = absolute pressure, t = absolute temperature, and A B C are constants. Both formulas are quoted from p. 283 of Rankine's "Rules and Tables;" or the same results may be more readily obtained from Regnault's Tables given at p. 263, Ganot's Physics (3rd edition).

Having had, however, frequent inquiries as to what could be done in actual practice by donkey-pumps for feeding boilers from hotwells, &c.; and supposing that possibly sufficient vapour might be evolved from the water at lower temperatures than those ascertained by the above rules to diminish seriously the quantity pumped, the Author carried out a series of experiments to obtain actual results.

The donkey-pump employed was single-acting, having a ram 3 inches in diameter, with a length of stroke of 7 inches. The pump was elevated to various heights; but the results being so nearly alike, allowing for difference in height and temperature, the Table given below for 15 feet may be taken as typical of all. The supply-tank stood on the ground, the water in it being heated by a jet of steam. The suction-pipe was led direct to the valve-box with only one bend, and the delivery-tank was elevated to about the same level as the pump, the water being discharged through a valve loaded to 60 lbs. per square inch. A large cock, fitted to the bottom of the delivery-tank, was kept open while the speed of the pump was being regulated, and was shut as soon as the trial commenced. A certain depth of water always existed in the tank while the cock was open; this was carefully gauged and deducted at the end of the trial. The speed of the pump was regulated as nearly as possible to that given in the first column, and on each trial, as soon as the exact number of strokes was completed, the pump was stopped.

It will be seen that the results agree closely with those given by the above rules, the falling off in the quantity at the higher temperatures being most probably due to the friction of the water in passing through the pipes, valves, &c. It will also be observed that the speed of the pump had to be reduced for the higher temperatures, the speeds stated in the list being found to give the best results.

RESULTS of EXPERIMENT No. 3 with the PUMP 15 FEET ABOVE the WATER-LEVEL.

Revolutions.	Temperature Fahrenheit.	Hot Water Pumped per Minute.
Per Minute.	°	Cubic Inches.
70	70	3,430
70	100	3,430
70	120	3,430
70	140	3,430
70	160	3,286
60	170	2,682
50	180	2,180

Each quantity stated is the mean of several trials. Above 180° Fahrenheit scarcely any water could be pumped. According to Regnault, 185° would be about the limiting temperature at 15 feet.

(*Paper No. 1961.*)

"On the Mechanical Examination and Testing of Portland Cement."

By HENRY FAIJA, Assoc. M. Inst. C.E.

It may be assumed that the object of testing cement is to ascertain its value for constructive purposes, and it is the aim of the Author to examine the tests to which cement is generally subjected, and to see how far they attain their object.

The requirements of any test or combination of tests are, that the conclusion shall be absolute, and that the time occupied in arriving at that conclusion shall be as short as possible; and further, as all opinions formed by the examination of a cement must be based on the results of previous examinations and tests, it is evidently of importance that a uniform means of testing should be adopted, so that users and manufacturers may be able to compare their own tests with those by other people. At present the tests made by one person are of little use to any one else, owing to differences of manipulation and detail.

The ordinary practice is to find the value of a cement by making it into briquettes and ascertaining their tensile-strength when seven days old, as well as by its fineness, weight, and colour; from the results obtained and their relative bearing to each other, a correct opinion is presumably arrived at.

Mr. Mann lately presented to the Institution the results of some experiments on the adhesion of cement to different materials, and by this means ascertained its value for constructive purposes.[1] Nor must it be forgotten that Mr. Grant has introduced the sand test into this country from Germany, which is another test for adhesion; for although the briquettes made of cement and sand are tested for tensile strength, it is the adhesion between the sand and the cement which gives the briquette its tensile strength. Whether either of these enables a more definite conclusion to be arrived at than the ordinary method, the Author does not venture to offer an opinion. He thinks, however, that neither of them is likely to supersede the generally accepted requirements of a test,

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[1] Minutes of Proceedings Inst. C.E., vol. lxxi., p. 251.

and that therefore they are detrimental to the interests of uniform testing.

The Author in this Paper first considers the details of manipulation and other matters affecting the results obtained in a cement-test, and afterwards the properties which a good cement should show in each detail.

In testing cement for tensile-strength several points materially affect the result; namely, the percentage of water used in gauging. The skill of the manipulator, which practically means the time occupied in reducing the cement to a proper consistency, and the dexterity in filling the moulds, so that a sound briquette free from air-bubbles may be obtained with the minimum of water in the minimum of time. The form and construction of the mould in which to form the briquette. The careful removal of the briquette from the mould and its subsequent handling. The time which elapses between the formation of the briquette and placing it in water. And the manner and speed at which the weight is put on the briquette when being tested.

It may be assumed that, as far as the tensile-strength is concerned, a better result than can possibly be secured in practice should be obtained in the testing-room; but it is of greater importance that a uniform result should be obtained by all persons engaged in testing cement, and that a uniform procedure should be adopted, than that the acme of perfection should be attained. The skill of the operator having a great deal to do with the result, it is necessary to reduce the operation of gauging the cement to, as nearly as possible, a purely mechanical process. This can be accomplished by a gauging machine devised by the Author.[1] It gives in ordinary hands as good a result as the most expert operator obtains when gauging in the usual way with the trowel. By employing the gauger the cement is brought to a proper consistency to be put into the moulds in considerably less time; and by reducing the labour and wrist-work necessary to properly gauge a cement, the inducement to slovenly manipulation and the use of more water than is necessary is obviated.

The advantage gained by adding the minimum of water for gauging has for some time been acknowledged, and the results of experiments by Mr. Grant and others, and by the Author, which have from time to time been published in the Proceedings of this and other Institutions, are sufficient to show that such is the fact. It is impossible to name a fixed quantity, as hardly any two cements

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[1] Appendix I., Fig. 1.

require the same, and it can only be determined by making experimental pats previous to proceeding with the test. The maximum amount of water may, however, be fixed at 18 per cent.

That the time occupied in gauging a sample of cement affects the result obtained is hardly a matter to prove by experiment, it being evident that if cement is worked after it has commenced to set, its nature must be altered, and the result cannot be reliable; this, though it applies in a more marked degree to quick-setting cements, is true of all.

The form of briquette must materially affect the result in testing for tensile-strength. The Author can only say that the form brought forward three years ago by Mr. Grant in a Paper before this Institution,[1] gives undoubtedly the best results, and he should like to see that form universally adopted.[2] It is hardly necessary to add that the moulds should be of metal; resting on glass, metal or other non-porous bed. If a porous or partially porous bed is used, any excess of water in gauging is quickly withdrawn from the briquette, and the setting being thus accelerated, a better result is shown at short dates, though eventually there would probably be no difference. But inasmuch as a test of cement for practical purposes never exceeds twenty-eight days, and is generally confined to seven, a misleading result is obtained if this detail be not attended to.

The next item of importance is the time allowed to elapse between the gauging of the cement and placing the briquette in water. Experiments prove that the greatest tensile-strength is obtained when the briquette is put in water directly it is set. With quick-setting cements this may be in an hour or two after gauging, and with slow-setting cements it may be extended to ten, fourteen, or twenty hours. The danger, however, is, that if this practice be adopted, in unskilful hands the briquette may be put in water a little too soon, when the cement would be acted upon detrimentally. It is therefore advisable that a given number of hours should be determined upon, and this by practice has been fixed at twenty-four hours.

In testing all other materials the rate of speed at which the weight or strain is applied is considered, but it seems to have been persistently ignored when testing cement. Its importance, however, must be as great with one material as with another. Mr. W. Matthews, M. Inst. C.E., and Mr. P. Adie, Assoc. Inst. C.E., have

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[1] Minutes of Proceedings Inst. C.E., vol. lxii., p. 98.

[2] Appendix II.

devised an automatic arrangement for running the weight along a steelyard, and it is fixed to most of Mr. Adie's testing machines. It ensures the weight being put on to the briquette at an even and regular speed, though no special speed seems to have been adopted. The principle on which it works is that of a falling weight governed by a water-brake. Dr. Michaelis' machine, in which the weight is applied by allowing shot to fall into a pan at the end of a compound lever, as well as Bailey's machine, in which water is used instead of shot, might both be easily arranged to apply the weight at a standard speed.

Notwithstanding the different results which it is evident would be obtained through variation in the speed of applying the weight, the Author is not aware of any exhaustive experiments having been made, or any conclusion arrived at on the subject; he has therefore given in Appendix III. the details of an experiment comprising over six hundred briquettes. The briquettes were broken at five different speeds, varying from 100 lbs. in one second to 100 lbs. in two minutes; these being considered the limits which it was possible to adopt in practice. By taking the average percentage of difference he has been enabled to draw a curve, showing the different results to be expected from applying the weight at different speeds. Though an experiment comprising only six hundred examples cannot perhaps be considered conclusive, yet it enables a fairly good average to be obtained, especially as several different cements were used throughout the experiment. Although in each series the same cement was used, the gauging was all done at one time, and in exactly the same manner, by the same man.

The results were as follow:—

Increase	per cent.	between	100 lbs. in	1 minute	and 100 lbs. in	2 mins.	3·960
„	„	„	„	30 seconds	„	1 „	3·528
„	„	„	„	15 „	„	30 secs.	4·928
„	„	„	„	1 „	„	15 „	10·726
Total	„	„	„	2 minutes	„	1 „	23·142

The great differences shown by this experiment must impress every user and manufacturer of cement with the importance of adopting a standard speed at which the weight is to be applied; and it seems that the most convenient would be either the 100 lbs. in fifteen seconds, which the Author uses in his testing room, or a little slower, but certainly not slower than 100 lbs. in thirty seconds, on account of the length of time which a test would occupy.

The Author is of opinion that by adopting the before-mentioned or similar means and appliances for gauging the cement and forming the briquettes, the results obtained by different experimenters would approach more nearly to each other, a better estimation of the value of a cement would be possible, and a comparison would be more easily and more definitely decided.

The determination of the fineness of a cement can of necessity only be carried out in one manner, and is not subject to error. The weight per striked bushel, however, is open to considerable argument. The manner in which the measure is filled is of necessity all important, it being assumed that the cement is to be put into the measure as lightly as possible. In Appendix IV. three different ways of filling the bushel are shown; first, that adopted by Sir John Coode, Vice-President Inst. C.E.; secondly, a method shown to the Author by Mr. Isaac Johnson of Greenhithe; and thirdly, the method used by the Author in his testing-room. They may all be considered appropriate ways of weighing cement, though Sir John Coode's gives a rather higher result than the other two, which is due to there being such a great fall (18 inches) for the cement. Mr. Johnson's and the Author's give as nearly as possible the same result, but the former is perhaps the easier to carry out.

As an alternative test or in conjunction with the foregoing, the specific gravity of a cement may be ascertained, with this advantage, that while the weight per bushel varies with the fineness to which the cement is ground, the specific gravity is of necessity constant.

The usual method of determining whether or not a cement will blow, is by making a few small pats and placing them in water as soon as they are set, which may be in one hour or two or more hours, according to whether the cement is quick or slow-setting, and by examining them daily to see if they develop cracks or otherwise alter in form. That the inference drawn from the result thus obtained is a true one, is extremely doubtful; and the Author has therefore adopted another method to determine what, in his opinion, is the most dangerous property that a cement can possess.

Some years ago the Author made numerous experiments with the view of accelerating the setting or hardening of cement and concrete, which resulted in his taking out a patent for that purpose. The process is only referred to because out of it has come a little apparatus of great value in the testing-room, which enables a decided opinion to be formed within twenty-four hours as to whether the cement under examination will blow, or if it is a safe cement to use. The principle of the Author's process for hardening is to subject the concrete immediately on gauging to a moist heat of about 90° Fahrenheit, and afterwards to keep it in a warm silicious bath at a temperature of about 100°. It was found that if by accident these temperatures were materially increased, the concrete sometimes gave all the appearance of having been made with a blowy cement. From this it was opined that a good cement would not blow at these temperatures, and further experiments have proved such to be the case, and also that a cement which does not stand this treatment is improperly made and will sooner or later blow. The Author therefore devised the apparatus, a sketch of which is given in Appendix V. It is a moist-heat chamber and bath combined in a small space; but the bath is only of water instead of being silicious. The mode of using it is to make a small pat of the cement under examination on a piece of glass and immediately to place it in the moist-heat part of the apparatus. When it is set, which, even in the case of very slow-setting cements, will be within two or three hours, it is taken out of the moist-heat chamber and placed in the bath. If next morning the pat is perfectly sound, it is decided that the cement will not blow; if, on the other hand, it is swollen and blown, then the cement is considered unfit for use. It would not, however, be fair to say that because under these conditions the pat was blown, it is an improperly made cement, for the blowing might be due to extreme freshness.

Under these circumstances, therefore, it is necessary to put a small quantity of cement on a tray in a thin layer, and to let it thoroughly cool for two or three days. If a pat made from this cooled cement blows when submitted to the influence of the moist heat and warm bath, the Author would on no account advise the use of the cement. On the other hand, if it does not blow, it is pretty clearly shown that the cement is sound but too fresh, and that the bulk should be turned over three or four times and cooled before use.

The Author proposes in the second portion of the Paper to consider the properties which a good and useful cement should develop when being tested, under three divisions; firstly, those properties which have already been amply experimented upon, and which may be considered as proved and acknowledged; secondly, those which may be termed the problematical, which though inherent to a good cement may also be found in a bad one; and thirdly, the absolute strength and behaviour of the cement at different dates.

Of the first, it may be considered that both users and manufacturers are cognisant of the importance of a cement being finely ground, and that, given a certain cement, the best result is obtained when it is finely ground. There is, however, a limit which commercially cannot be exceeded, except of course at an increased price, or until other machinery has been invented for grinding. This limit seems to be that the cement shall all pass through a sieve having 900 meshes to the square inch, and shall not leave more than 10 per cent. residue on a sieve having 2,500 meshes to the square inch. This degree of fineness is for all practical purposes sufficient; and if a user thinks he can obtain a better result by having a finer-ground cement, he should be prepared to pay a higher price for it.

The weight per striked bushel, specific gravity, or density of a cement, are in the highest degree problematical tests. It is assumed that a heavy cement means one with a proper quantity of lime in its composition and well calcined, and a light cement the reverse; but it does not of necessity follow that such is the case. It is also possible to have a cement too heavy, and, as pointed out by the Author ten years ago, and by others since, the weight must bear a definite relation to the fineness. Of necessity, the finer the cement the lighter it will weigh. It is generally considered that a cement of the fineness previously specified should weigh from 110 to 114 lbs. per striked bushel, when the bushel measure is filled in a manner similar to that adopted by the Author. The specific gravity corresponding to this weight and fineness is from 3·00 to 3·08.

The colour of a cement is almost too problematical to deserve consideration, except when examining cements made from similar materials, as the varying properties of different raw materials must of necessity affect the colour. But the Author puts very little value on these problematical tests as a means of assisting in the determination of the value of a cement.

The absolute behaviour of the cement when made into briquettes and tested at different dates, and the careful examination of its behaviour during gauging and setting, are the best means for determining its value for constructive purposes.

The determination of what the tensile strength of a cement should be at certain dates, is the one point on which all authorities seem to differ, and yet it is the one test which has been experimented upon more than all other tests put together. If, however, all the experiments which have been published are examined, it does not seem difficult to arrive at a just conclusion. The Author has made thousands of tests in this direction; he has examined all the tests which have been published in England, and some of those from Germany, and the result of these tests and examinations is, that good cement, which practically continues to increase in strength for a period over which it is possible to make a test, has a tensile-strength, when tested in the ordinary manner, of not more than 300 lbs. or 350 lbs. per square inch at the expiration of seven days from gauging; while the same examination shows that many of those cements which at the same age carry 400 lbs. or 500 lbs. actually deteriorate before they are a year old.

The Author is of opinion that the strength at a single date does not define with sufficient accuracy the value of a cement; but that two dates should be determined upon, and the increase per cent. in strength between those dates will better define the nature of the cement than the actual strength at either. As an example, the two following cements may be cited:—

—	3 Days.	7 Days.	28 Days.	3 Months.
No. 1	390	460	520	510
No. 2	205	375	490	590

Consider the behaviour of No. 1 cement up to twenty-eight days. It is superior in every way to No. 2; though the increase of strength between each date is but little, while No. 2 increased 85 per cent. between the three and seven days, and 30 per cent. between the seven and twenty-eight days. The latter therefore appears, as indeed is proved by the result of a three-months' test, to be still increasing in strength, and likely to do so for some time, while No. 1 is a cement which develops all its strength in a short period. It is therefore not likely to increase in strength with age, and may possibly deteriorate. It would not, however, satisfy the case to define only the increase per cent. which should take place between certain dates; but a minimum and maximum strength should be determined upon at the earlier date, as indicative of a good cement, and a specified increase above that for all future tests named. In the Author's opinion, the tensile-strength of a briquette three days old should be at least 175 lbs., and should not exceed 275 lbs. per square inch; the increase of strength between the three days and seven days should be from 40 to 50 per cent.; and if a twenty-eight days' test is adopted, the increase should be from 20 to 30 per cent. of the strength shown at the seven days.

A slow-setting cement does not practically increase in temperature during setting; it is only the quick-setting ones which develop this characteristic. Many quick-setting cements when fresh will increase in temperature as much as 16° and 18° Fahrenheit in eight or ten minutes from gauging, and will not return to their normal temperature for more than an hour. If cement possessing this characteristic be cooled, it will be slower setting, and the increase in temperature during setting will not be so great. This test may therefore be often useful in assisting in the immediate determination of the value of a cement.

The Author maintains that there should be a uniform standard specification, compliance with which would ensure a thoroughly good and sound cement, which manufacturers would be able and willing to supply at the ordinary market prices. A standard specification has been for many years adopted in Germany and other countries, and has proved of great benefit to the industry, and there is no reason why it should not be equally beneficial in this country. Shippers, and users who require only a few hundred tons at a time (and it must not be forgotten that these take up the bulk of the cement made in this country), would know that they were obtaining a good and useful article. Such an arrangement would in no way interfere with engineers, or others who use large quantities, adopting their own specification, and there is no doubt manufacturers would be prepared to comply with their demands under special conditions. In order, however, to ensure success, a standard specification should be one which, while meeting all requirements, should be simple and conclusive, and at the same time expeditious. In nine specifications out of ten, many of the items demanded are contradictory, and many often useless. It therefore seems necessary to examine the clauses usually inserted in a specification, and see what assistance they render in determining the value of the cement, so that the actual clauses in a specification may be reduced to a minimum. Taking them in order, they generally appear to be: first, the weight; second, the fineness; third, the examination of pats; fourth, the colour; fifth, the tensile-strength at seven days; sixth, that the cement shall set in a certain time.

Notwithstanding that this hitherto has been considered a good and efficient test, the Author believes no correct estimate of the value of the cement can be arrived at by the comparison of the results obtained, and therefore would substitute for them the following:—

First, fineness; second, absence of blowing, determined by the use of the apparatus already described; third, the tensile strength at three and seven days, and the increase per cent. between those dates. In addition, a twenty-eight days' test might be adopted if practicable; but in many cases—certainly in all cases of shipment—it is impossible to allow the examination of the cement to extend over such a long period.

The Author has already expressed his views on the details of such a specification, and of the details and uniform method of manipulation, and has embodied them as a suggestion in Appendix VI.

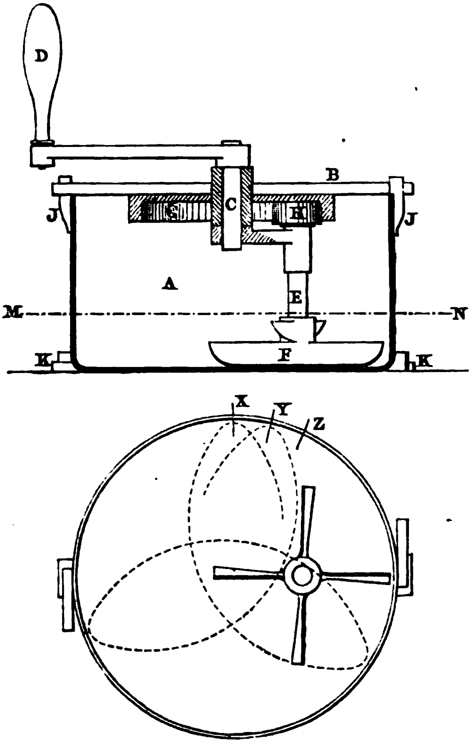
The Paper is accompanied by several diagrams, from which the wood-cuts in the Appendices have been engraved.

APPENDICES.

I. Cement Gauger (Fig. 1).

In the accompanying sectional elevation A is the mixing pan, B being a movable open cover which carries the spindle C, to which is connected the handle D, the stirrer spindle E, and the mixer or stirrers F. G is an internal toothed wheel fixed to the cover B, and H is a pinion keyed to the stirrer spindle E, and working in G. The cover B is held in position by the clips J J, and is easily taken off by first turning it partially round. The whole machine is fixed to the table or bench by similar clips K K, so that it is easily taken up and emptied. The toothed wheel G has one or two teeth more than a multiple of the teeth in the pinion, so that at each revolution of the handle the stirrers come to a

Fig. 1.



Plan at M N.

Scale 2 inches = 1 foot.

different position in the pan. The travel of one end of a stirrer is shown by the dotted lines in the plan, by which it is seen that at the first complete revolution that point is shifted from X to Y, and at the next revolution that point would come to Z, so that it takes a considerable number of revolutions for the stirrer to come back to absolutely the same position. The stirrers are slightly bent in the form of a screw, and the two, one above the other, are placed at right angles to each other; by this means the whole of the cement is thoroughly gauged; by turning the handle in one direction the cement is forced to the bottom of the pan, and by turning it the other it is slightly lifted. With this arrangement of gearing the stirrers revolve round the pan in one direction, and on their own axes in the reverse. The pan is 10 inches in diameter and 6 inches high, and it easily gauges about 4 lbs. of cement at a time, which is sufficient for ten briquettes of the 1-inch section.

The mode of working the machine is as follows: the pan is first fixed in the clips K on the bench, and the weighed cement put into it; the cover is then put on and fixed in the clips J; the measured water is added all at once, and the handle turned (not too quickly) for one or two minutes; the cover with the stirrers is then taken off, the pan removed from the clips K, the cement beaten together to one side of it with a spatula, and turned on to the gauging slate. The cement has now only to be trowelled together into a convenient form and placed in the moulds in the usual way. The machine has been made in a variety of forms for mixing powders and other substances.

The following examples of cement gauged by hand and with the gauger are sufficient to show that the cement loses nothing by being treated mechanically, though, in the Author's opinion, it would not matter if the results obtained with the gauger were not so good as by hand-gauging, as it must secure a more uniform result than is possible by different operators.

COMPARATIVE RESULTS.

Sample No. 1.

Gauged by Hand.			Gauged with Gauger.		
No. 1.	475	471 average.	No. 1.	440	481 average.
„ 2.	455		„ 2.	480	
„ 3.	485		„ 3.	485	
„ 4.	450		„ 4.	500	
„ 5.	490		„ 5.	500	

Sample No. 2.

No. 1.	570	594 average.	No. 1.	695	650 average.
„ 2.	600		„ 2.	575	
„ 3.	595		„ 3.	655	
„ 4.	645		„ 4.	695	
„ 5.	560		„ 5.	630	
			„ 6.	655	662 average.
			„ 7.	595	
			„ 8.	650	
			„ 9.	720	
			„ 10.	690	

Sample No. 3.

No. 1. 990
„ 2. 885
„ 3. 770 } 847 average.
„ 4. 830
„ 5. 760

No. 1. 825
„ 2. 920 } 872 average.

„ 4. 1,090
„ 5. 1,070 } 1,080 average.

II. FORM OF BRIQUETTE.

The form of briquette is substantially the same as that designed by Mr. J. Grant, M. Inst. C.E.,[1] being only slightly altered at each end.[2] The Author found that the flat top adopted by Mr. Grant necessitated the use of a loose plate in the mould in order to facilitate the removal of the briquette. To obviate this the Author altered the end, so as to enable the mould to be drawn from the briquette without strain or friction. The point at each end of the briquette also greatly assists the operator in placing the briquette in the clips perfectly vertical and square.

III.—SUMMARY of RESULTS of EXPERIMENTS to DETERMINE the DIFFERENCE OBTAINED by APPLYING the WEIGHT to the BRIQUETTE, when TESTING for TENSILE STRENGTH at DIFFERENT SPEEDS.

Number of Briquettes.	Speed.	Average Result.
	lbs. Secs.	lbs.
129	100 in 1	560·75
129	100 „ 15	506·43
145	100 „ 15	452·20
145	100 „ 30	430·96
90	100 „ 30	417·27
90	100 „ 60	403·05
40	100 „ 60	416·75
40	100 „120	400·87

From the foregoing results it will be seen that the increase per cent. due to increased speed of applying the strain is as follows:—

Taking the lowest speed of 100 lbs. in 120 seconds as a starting-point, by applying the strain at the rate of—

100 lbs. in 60 seconds the increase is 3·960 per cent.
„ „ 30 „ „ 7·488 „
„ „ 15 „ „ 12·416 „
„ „ 1 „ „ 23·142 „

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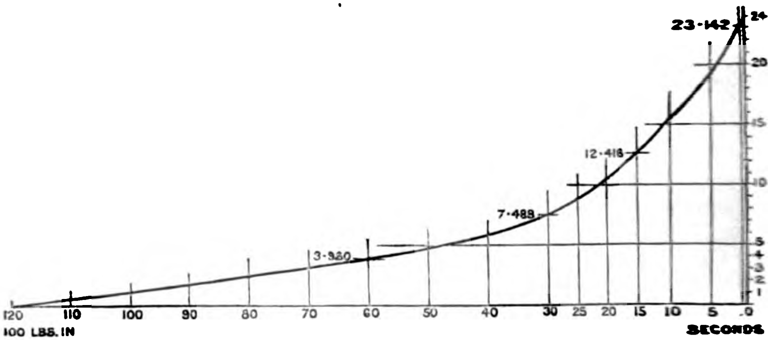
[1] Minutes of Proceedings Inst. C.E., vol. lxii., p. 207, Fig. D.

[2] *Ibid.*, vol. lxvii., p. 350.

From these results the accompanying curve of fracture has been obtained (Fig. 2).

FIG. 2.



Curve of Fracture obtained by applying the Strain at different Speeds.

IV. FORMS of APPARATUS for FILLING the BUSHEL MEASURE when MEASURING CEMENT.

No. 1.—That in use by Sir John Coode; No. 2.—That used by Mr. Isaac Johnson, of Greenhithe; and No. 3.—That used by the Author.

SIR JOHN COODE'S METHOD. FIG. 3.

A is a hopper into which the cement to be weighed is shovelled, having a circular mouth at B; in the centre of the hopper extending below the mouth is a square cone C. Thus the only exit for the cement from the hopper A is the space left between the square cone fixed in the round mouth of the hopper, as shown in plan. D is the bushel measure, and the height from B to the top of the measure is 18 inches, and the height from the top of the measure to the base of the cone C is 9 inches.

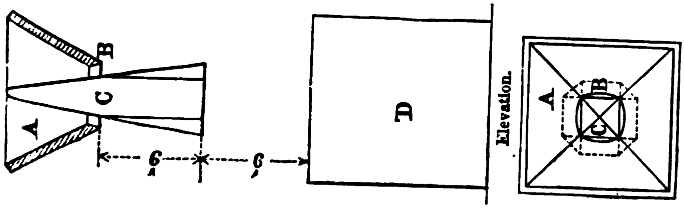
MR. ISAAC JOHNSON'S METHOD. FIG. 4.

A is a stool of sufficient height to allow the bushel measure B to be placed under it, and of such a width as to carry the sieve D comfortably. The sieve D is of large enough mesh to admit of all the cement passing through easily, the cement being put in the sieve and sifted through until the measure is full. When the top of the measure is 6 inches from the wire of the sieve, this apparatus gives practically the same result as the Author's.

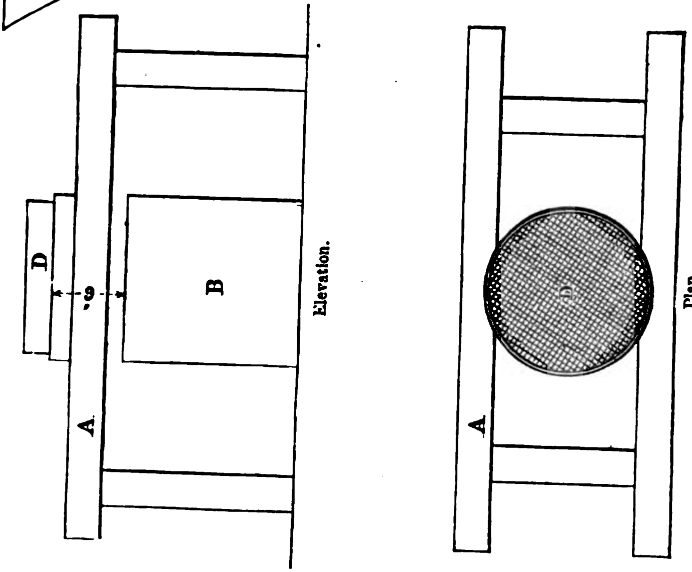
THE AUTHOR'S METHOD. FIG. 5.

A is a hopper having a canvas stocking B at its mouth, C is a half-round zinc shoot fixed at an angle of 35°, the mouth of which is 5 inches above the top of the measure D. The cement to be weighed is placed in the hopper A, and the run of the cement down the shoot C is regulated by holding the stocking B in the hand.

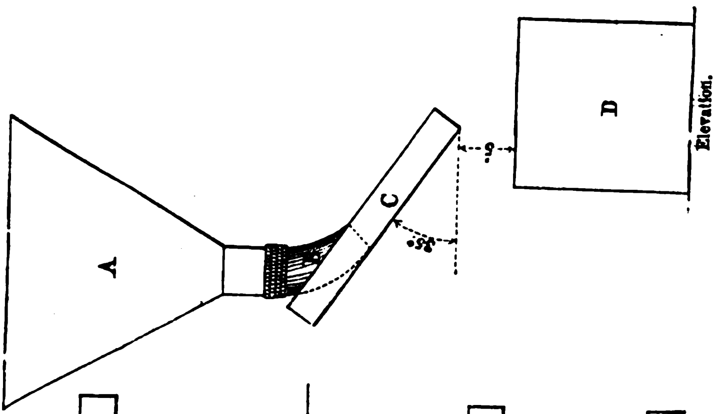
Figs. 3.



Figs. 4.



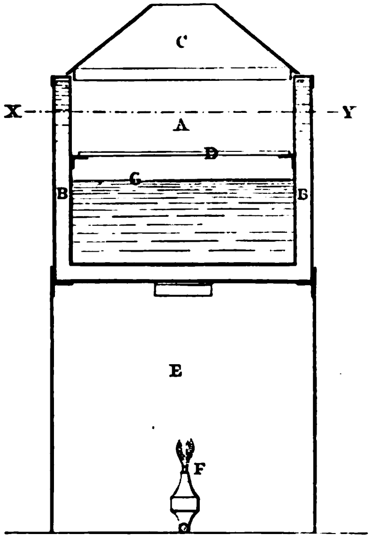
Figs. 5.



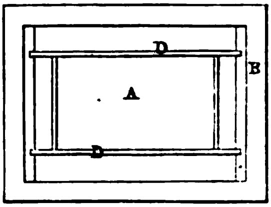
V. Apparatus used by the Author for determining in a few Hours if a Cement is of a blowy nature. Fig. 6.

It consists of an inner vessel A, enclosed in an outer one B, the space between the two being filled with water; C is a cover having a small aperture at the top; D is a stand on which to place the pats; E is an enclosed stand in which is the gas-jet F. The vessel A is 7 inches long by 5 inches wide by 6 inches high; it is filled with water up to about the height G. The gas-burner F is regulated to maintain the water in A at the temperature of 110° Fahrenheit; it is fitted with a governor so that alterations in pressure from the main do not affect the size of the flame. The slight evaporation from the water in A supplies the moisture necessary for the upper part of that vessel, which is warmed by the hot water between the two vessels. The apparatus has been designed so that when the water in A is at 110° the upper part of A is at about 100°.

Fig. 6.



Sectional Elevation.



Plan at X Y.

Scale 4 inches = 1 foot.

Immediately the pats of cement are made, they are placed on the stand D, in the moist-heat portion of the vessel A; as soon as they are set they are taken off the stand and put in the water in the same vessel, where they are left until the next day, when they are examined and conclusions arrived at as mentioned in the body of the Paper.

VI. Proposed Suggestions or Definitions.

In order to ensure a uniform procedure in carrying out a test of cement the following suggestions or definitions are proposed:—

1. *Fineness.*—That the fineness to which a cement is ground shall in all cases be determined by sifting it through ordinary copper-wire sieves having a square mesh of the standard gauges.
2. *Moulds.*—That the form of mould used for making the briquettes shall be substantially that known as Mr. Grant's design.[1] The moulds to be of brass or gun-metal, and to rest on metal, glass, or other non-porous bed.
3. *Briquettes.*—That the briquettes for testing the tensile-strength shall have a sectional area at the point of fracture of 1 square inch. That in all cases the average of at least five briquettes shall be taken as a test at any given date, and that it is desirable that the five briquettes be made from one gauging.
4. *Gauging.*—The cement to be formed into pats and briquettes, to be gauged with not more than 18 per cent. of water. The briquettes to be placed in tanks of water twenty-four hours after gauging, and to remain there until due for testing, when they are to be taken out and tested immediately.
5. *Testing.*—When testing the briquettes for tensile strength, the weight to be applied at the rate of 100 lbs. in fifteen seconds.
6. *Expansion or Contraction.*—That the freedom of a cement from blowing shall be determined by the use of the apparatus described in Appendix V., that the temperature of the moist heat be maintained at from 90° to 100° Fahrenheit, and that of the bath from 100° to 110° Fahrenheit.
7. *Water.*—That the water used for gauging and for the tanks in which the briquettes are placed shall be ordinary fresh potable water.

The Author is further of opinion that the following specification would satisfy all requirements, and ensure the delivery of a good and sound cement.

1. *Fineness.*—To be such that the cement will all pass through a sieve having 625 holes (25^2) to the square inch, and leave only 10 per cent. residue when sifted through a sieve having 2,500 meshes (50^2) to the square inch.
2. *Expansion or Contraction.*—That a pat made and submitted to moist heat and warm water at the temperature and in the manner already described (Appendix V.) shall show no signs of blowing in forty-eight hours.
3. *Tensile Strength.*—Briquettes which have been gauged, treated, and tested in the prescribed manner, to carry an average tensile strain without fracture of at least 175 lbs. at the expiration of three days from gauging; and those tested at the expiration of seven days from gauging, to show an increase of at least 50 per cent. over the strength of those at the three days.

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[1] Minutes of Proceedings Inst. C.E., vol. lxvii., p. 350.

(Paper No. 1970.)

"Spontaneous Combustion in Collieries."[1]

By —. DURAND.

Translated and Abstracted by ALFRED BACHE, B.A., Assoc. Inst. C.E.

Causes.—The primary causes of fires breaking out in collieries where the coal is contaminated with pyrites are believed by the Author, who is engineer of the Doyet Collieries[2] in the department of Allier, France, to be the three following:—oxidation of pyrites, friction from slippings, and warmth of air-current. Experiments made by Mr. Fayol have shown that above ground a heap of Commentry small coal, presenting to the air a surface of not more than about 1¾ square yard per cubic yard, will, if once it gets heated to a temperature that lies somewhere between 140° and 212° Fahrenheit, go on heating more and more till at length it takes fire.

Pyrites met with in coal-seams is either amorphous or crystalline, and occurs in the shape of nodules, flakes, bunches, or veins, while sometimes it is so finely disseminated throughout the coal as to be invisible. In dry air and at low temperatures it does not oxidise; but its dissemination through coal or shale gives it a more porous character than appertains to it by itself, and in almost all cases it oxidises in moist air and becomes converted into sulphate of iron, the excess of sulphur being set free. The heat developed by the oxidation is further augmented, where there is sufficient moisture present, by the subsequent conversion of the sulphate of iron into hyposulphate, with liberation of sulphuric acid, which, when mixed with one quarter its weight of water, rises to the temperature of 220° Fahrenheit. Various other chemical actions also conduce to the development of heat; while there is no absorption of heat by the formation of any gas during the oxidation of the pyrites. At Doyet Collieries the roof over the thick seam of

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[1] The original article appeared in the "Bulletin de la Société de l'Industrie Minérale," 1883, vol. xii., pp. 43-89.

[2] It will be borne in mind that in many of the collieries in the Midland and other coalfields of France the seams are not only of great thickness, sometimes even more than 20 yards, but are also inclined at steep angles, sometimes nearly vertical.—A.B.

coal is composed in some places of fine shaly sandstone containing pyrites; and near the outcrop, where cracks have occurred in the roof, the moisture from the surface and the air from the mine, penetrating into them, have caused the roof to get red-hot, and to set fire sometimes to the timber props. A mere bunch of pyrites, however small, occurring either in the coal itself or in a shale parting, is quite sufficient to serve as a lucifer-match for starting a conflagration. The sulphur liberated by decomposition of pyrites burns at 480° Fahrenheit, and any sulpho-carbons which may also be formed burn at about 660° Fahrenheit; whilst the hydro-carbons of coal will not burn below 930° Fahrenheit at least. Hence pyrites, as furnishing the most inflammable products, is really what gives the start to a fire.

Where pillars of coal become cracked and crushed under the pressure of the roof, slippings occur, producing considerable friction, which develops corresponding heat; and as the surfaces sliding past each other are uneven, the friction and heat are concentrated upon the prominences in contact. The heat thus becomes sufficient not merely to accelerate the action of pyrites, but possibly to ignite coal seemingly free from pyrites, even anthracite hard to burn. In the open working at the outcrop at Doyet, the coal has been set on fire by a sudden slip of the ground above.

An air-current that was warmed by uncondensed steam discharged from an underground engine at Doyet caused a little small coal, which had accumulated against some timbering, to get so hot that the timber took fire after the engine had been at work rather more than three months. In return air-drifts the crushed coal in the roof is particularly liable to heat under the influence of the warm and moist current.

In seams free from pyrites, the Author believes oxidation of the hydro-carbons on exposure to air cannot develop heat enough to ignite the coal; and the only way in which he can account for spontaneous combustion in such coal is by the presence of dust or fine slack in the midst of any heaps that are found to be heating. Dust and fine slack he considers capable of exerting a condensing power upon the combustible gases that are ready to escape from bituminous or gaseous coal, and also upon the oxygen of the air; and the heat so developed may become sufficient to fire the gas, and thereby the coal.

While therefore spontaneous combustion may occur in any colliery, whether the coal contain pyrites or not, it is more particularly in seams of caking coal, containing pyrites, that, as the workings progress, the pillars left standing grow hot rapidly, under the combined action of oxidation of pyrites, pressure and subsidence of roof, and oxidation of hydro-carbons through condensing power of dust. It is the pyrites however which, wherever present in any appreciable quantity, plays the principal part in starting ignition, and thus constitutes the primary cause of fire; the other causes are then but secondary, although they may so far supplement the start thus given as to make a seam containing but little pyrites appear readier to fire than one containing much more.

Development.—The development of spontaneous combustion is considered by the Author firstly in the case of masses of coal, such as pillars left in working. Really solid pillars never fire; those that do are always fissured with numerous cracks, and are more or less crushed. Outbreaks of fire are encouraged by the presence of any coal crushed small, which in its finely subdivided state promotes the chemical actions that induce heating. Fire first smoulders at the bottom of the innumerable cracks by which the pillars have become fissured under the crushing load they have to support; then the walls of the cracks get red-hot and burn, sometimes bursting suddenly into flame where the previous heating has covered them with bituminous matter. The tarry smell thus occasioned often betrays the existence of fire before it has become visible; and so difficult is it to find its actual seat, that often it is not discovered until it has crept outwards towards the air-current at the mouth of the chinks, and has ignited the crushed coal behind the timbering of the roads, and then the timbering itself. The danger is augmented wherever there are timbered excavations overhead; and still more wherever a timbered drift has been pushed forwards under a mass of crushed coal overhead. Through such a mass air circulates easily, heat and moisture collect there, and fire breaks out quicker than where the overhead coal has been got out previously.

Wherever crushed coal can be harboured on or amongst the rubbish that is packed into the goaf, fire is sure sooner or later to break out. It begins at some distance in from the roads, and creeps out gradually towards them, igniting on the way any timber that may have been left buried in the gob-packing; the pungent wood-smoke gives immediate warning of the fire.

Pillars purposely left unworked, either for maintaining a shaft or because the coal in them is not good enough, are also liable to take fire. The load bears unevenly around them, they crush and crack under it, and small crushed coal accumulates next to the gob-packing; the heavier the pressure, the sooner do the pillars heat and fire. Similar circumstances occur where a nip in the seam stops the getting of coal.

Where the goaf is not packed with rubbish, but the ground is left to fall in, there is certain to be fire if any crushed coal is left behind. The danger is liable to be enhanced by accumulation of explosive gas in the large cavities; as is the case also wherever cavities result from settlement of rubbish packed in the goaf.

As to collieries being set on fire from a lamp or an explosion of fire-damp, the Author considers this can only occur where the mass so ignited has got very hot beforehand, and is ready to catch fire in a moment. An explosion moreover throws down a lot of coal that will easily take fire, besides shaking and splitting the pillars, and so rendering them more ready to ignite.

Hard seams of caking coal, containing much gas and pyrites, are the most liable to spontaneous combustion. In very fiery seams the Author has noticed that heating occurs generally in the dampest places, or along return air-ways when the air is warm and moist. Where a pillar of bad coal had stood without heating for seven years at the foot of an incline in a current of fresh air from the downcast shaft, an alteration in the ventilation exposed it to the return current of warm moist air, and it then got so hot in two months as to necessitate its speedy removal; by the time it could be worked, it was already too hot to touch in some places.

The nature of the roof tells variably. In some collieries fire is found to break out more readily under a roof of tender shale than under one of thick hard sandstone. At Doyet on the contrary, the thick sandstone roof, settling unevenly after the workings, leaves roof cavities, in which air circulates and encourages heating; while in places where a ceiling of shale separates the coal from the thick sandstone, the shale falls, and no dangerous cavities are left.

Coal or rubbish tipped in heaps above-ground from the pit-mouth is liable to heat and fire by oxidation under the action of the air and wet, wherever the smaller stuff that collects at the top of the heap is combustible enough. The fire breaks out first a little below the top, on the side most exposed to the wind; and spreads thence throughout the entire tip. It is sometimes started direct from the braziers burning at the pit-mouth to light the landing of the cages; the tip then ignites first at the top, whence the fire spreads downwards and laterally.

Prevention.—If the coal in a seam could only be preserved from getting crushed and fissured by increased pressure in working, or at any rate if all access of air could be cut off from it when so injured, its spontaneous combustion would be prevented. In the rare cases of quarrying an outcrop, the coal, as long as the overburden can be removed, can be worked in successive courses or steps from the top of the seam downwards, and can thus be got whole throughout the entire thickness of the seam. If the overburden be sent down the pit to serve as rubbish for packing the goaf in underground workings progressing simultaneously, the open-air working can be continued to a somewhat greater depth: at the risk however of finding that the deeper coal so reached has been already injured by settlement due to the underground operations.

When coal is got underground in successive courses or steps one below another from the top downwards, no packing in the goaf, not even were it masonry, will entirely prevent settlement of the superincumbent mass, whereby the coal in the lower and later-worked steps is always more or less crushed. A partial remedy consists either in packing with rubbish of a clayey nature, which consolidates into a more compact mass; or in leaving a sufficient thickness of coal underneath the packing of the goaf in the topmost course, and afterwards getting out as much as possible of this thickness, by working backwards below it and packing the goaf of the lower working also; or again, in timbering the floor of each course so thoroughly as to form a roof for the subsequent working of the next course below. But these methods, besides being costly and yielding a low output with a large proportion of small coal, are not always successful in obviating spontaneous combustion: still less so when the goaf is not packed at all, but is left to fall in.

What has to be guarded against is an actual outbreak of fire; so long as the coal is merely heating, the small quantity of noxious gas given off hardly matters, and the only drawback is that the workings sometimes get inconveniently hot for the men. The longer all risk of firing can be staved off, the more possible will it be to adopt the mode of working that will yield the largest output at the lowest cost:—namely, in seams inclined at steep angles, by laying out the workings in successive stages or panels of great height (measured up the slope), which entails less expense for the preparatory operations of laying them open; several of these stages are then worked simultaneously, the getting of the coal being proceeded with in each stage from the bottom upwards, by a succession of horizontal courses or excavations. By this method the bottom courses in each panel feel the roof-pressure least, and yield a great quantity of large coal, which is won without difficulty, and with less risk of heating and firing. But in the uppermost courses the coal gets more or less crushed by the augmented pressure; hence, to avoid fire, there must be some limit to the total height of each panel, or rather to the number of courses contained in it, the bottom courses being of greater height than the upper. In a thick and well stratified seam of strong coal, containing not many partings, and inclined between 14° and 30° to the horizon, the total height of each panel may be 26 yards, measured up the slope, and the height of the bottom course 8 yards. But in the main seam at Doyet, which though hard is of variable quality and too liable to fire, the height of the courses is only that of a single tier of timber props, say 2 to 3 yards. Here four courses can be got, and a fifth started, without any fire having broken out; only no course must take more than six months in getting, and all the goaf must be thoroughly filled in. Quick getting is indispensable for avoiding fire in seams that fire readily. Usually by the time the fifth course is reached, the broken coal it contains is already hot, and great care is needed to prevent its burning whilst getting; hence five courses would seem to be the general limit for the height of a panel. As soon as the third course from the bottom is being got in any panel, the getting can be started of the bottom course in the next panel below; if the working of the lower panel were begun sooner, that of the upper would be endangered by settlements.

Alike in laying out the roads and in getting the coal, care must be taken to avoid the formation of roof cavities, from which start cracks that radiate through the seam; such cavities are most liable to occur at junctions of roads, and are to be guarded against by careful timbering, which must be well watched. Large cavities occurring in spite of these precautions should be cleared out, and then thoroughly filled in with good packing of small rubbish brought from above-ground. Where gob-roads have to be kept open for working or ventilation, they should either be shifted so as not to run through the middle of the goaf, but along its margin; or else they should be walled thick enough with good packing impervious to air and moisture, particularly when used as airways. They should be kept at a safe distance from any crushed pillars that have been abandoned in working.

The advantages of packing the goaf with rubbish are, that the workings are thereby kept cooler, settlements are less extensive, pillars get less crushed and are therefore less liable to heating, and fewer dangerous roof-cavities occur in which an outbreak of fire would be difficult to extinguish. In packing composed of friable stuff, the smaller bits fill up the spaces between the larger; and, if of a somewhat clayey consistency, the whole compacts under the load into a solid mass impervious to air. Good packing of this kind should always be used in the bottom courses of each panel; then by the time the top course is reached in the next panel below, the coal will there be got under a roof as compact as solid sandstone.

Spoil got from stone-drifts should not be used for packing the goaf; the large blocks of stone are too hard to crush under any settlement overhead, and air can pass too freely amongst them. In working a panel where the bottom course had been wholly packed with spoil got from sinking a shaft and from driving stone-drifts, notwithstanding that the spoil itself was incapable of heating, the Author found that pillars of considerable size, which had been left behind in the midst of this spoil because not worth getting, grew hot so rapidly as to be taking fire by the time the second course was finished and the third begun. It was only by then surrounding this dangerous goaf with small rubbish carefully rammed in, that the winning of the coal could be finished to the top of the panel. Some years later, when the working of the next panel below came in under the same place, similar trouble from heating had to be encountered. Hence the Author regards any spoil got underground as so bad for packing the goaf, that it should never be used unless the precautions are taken to pick out of it all stuff that could burn, and even then to keep it clear of contact with any masses that can heat. It is indeed by no means a dead loss to send up all such spoil to bank, and throw it over the tips, where after two or three years' exposure to the atmosphere it may, if meanwhile prevented from burning, become good enough to send down again into the pit for use as packing.

The best packing of all consists of loamy earth, and surface strata more or less disintegrated; the former is necessary wherever access of air has to be stopped at once without waiting for the roof to settle down heavily upon the packing. Where the goaf is well packed with good stuff, the timbers, whether upright props or roof-slabs, can be left behind to become crushed by the load and buried in the packing; otherwise they should be removed, even if only partially, as a precaution against fire. By way of rendering the rubbish-tips at the surface sooner ready for use as packing, it is sometimes thought desirable to let them burn as freely as may be. But this opinion is not shared by the Author, who considers that not only will a tip take a very long time to burn through to the middle, but that, after the fire has all burnt itself out, the ashy stuff will be too light, too dusty, too hot, and not binding enough, to be suitable for sending underground. Nevertheless even such burnt rubbish is preferable to spoil got underground and packed there at once.

Ventilation by a forced current of air under pressure has been found by the Author to be favourable to spontaneous combustion. Whether compression or exhaustion be employed, the greater the difference of pressure between the entering and the return air-currents, the more readily will the air penetrate cracked and crushed coal, and thereby promote heating and firing. In this respect, sharp turnings or narrowing of roads, and air-doors situated in a strong current, in the midst of crushed pillars or badly packed rubbish, are sources of danger, as are also inclines rising steep, and upcast pits. Hence, wherever an inlet air-way runs at all near a return air-way, the intervening pillars or ribs of seemingly solid coal require specially careful watching.

The coolness of the air-current is practically of no value for preventing, though it may somewhat retard, the heating of cracked pillars, or of broken coal that has fallen from roof-cavities or elsewhere. In a colliery where an old drift 4½ yards long, from a shaft to an inlet air-way, had been closed with rubbish carefully packed, the subsequent settlement of the packing had left a space above, into which a little crushed coal had fallen from the roof; the coolness of the ingoing air did not prevent this slack from heating and beginning to burn; and it had to be all cleared out, and earth rammed in its place.

A return air-current should never have to go downhill, otherwise it accumulates heat and moisture at the upper end of the descent, thereby favouring spontaneous combustion at that place. Where distant workings are liable to be insufficiently ventilated, owing to negligence in maintaining former roads now used as air-ways only, fresh air should be supplied direct to them, either by splitting the main ingoing current, or by sinking a new shaft from the surface. It is better to split the air than to course a single current through too great a length, because the latter means greater difference of pressure, attended with more risk of fire.

At the Doyet collieries, wherever the seam is not thick enough to work by the foregoing method of horizontal courses, and where the expense of laying out the workings on that method would be too great, the plan is followed of getting the coal in inclined courses, that is by pushing the working faces forwards uphill along the slope of the seam, instead of horizontally along its strike.

The uphill courses however are more difficult to keep open, and are liable to worse falls; each course takes longer to get, so that the surrounding crushed coal runs greater risk of heating, and this risk is further enhanced by the augmented draught consequent upon the air-current passing up the slope from the lower to the upper end of the course; hence fire breaks out more readily, while it is also more difficult to contend with on the slope than in horizontal workings. On the other hand, the rather larger quantity of packing used in uphill than in horizontal courses is an advantage against fire.

Firing of slack-heaps above ground can be effectually obviated, in the Author's opinion, only by completely precluding all penetration of air into them. To ventilate them, with the idea of keeping them cool, he considers as ineffectual and as dangerous as to let air penetrate crushed coal in the pit. From experience of its success in smothering fires on the sloping banks of outcrop workings, he recommends the expedient of covering the slack-heaps with a layer of refuse slimes from the coal-washers. Such a covering, being coaly and not clayey, does not set hard and crack, but follows readily any subsidence of the stuff beneath it. A layer 12 inches thick he believes would be an ample protection against firing, or even heating; and he suggests that on shipboard spontaneous combustion in coal cargoes might be altogether obviated by a layer 6 inches thick, the coal being so stowed as to prevent the covering of slimes from disappearing into the interstices. To prevent spoil-tips from firing, the stuff should be tipped in a layer too thin to heat under the action of the air; and should be left long enough exposed, before tipping the next layer over it; if it be also freed beforehand from all coal that can be utilized, so much the better.

(*Paper No. 1973.*)

"Dredgers and Dredging on the Tees."

By JOHN FOWLER, M. Inst. C.E. (of Stockton).

DREDGING operations in the Tees are of comparatively recent date. In 1824 a small dredger was hired and employed for some months upon a hard shoal at the east end of the second cut, immediately below Stockton. It was, however, a very inefficient machine, the time spent over repairs being more than that occupied in dredging.

Exclusive of the Priestman grab, the Commissioners have now four dredgers, No. 2 having the ladders outside, and the other three working in separate wells.

Their principal dimensions are as under:—

—	No. 2.	No. 3.	No. 4.	No. 5.
	Feet. Ins.	Feet. Ins.	Feet. Ins.	Feet. Ins.
Length	112 0	125 0	135 0	140 0
Breadth	29 0	34 0	34 6	34 6
Depth	9 0	9 6	10 6	10 6
	Ins. Ins.	Ins. Ins.	Ins. Ins.	Ins. Ins.
Cylinder	33 × 36	35 × 40	35 × 40	35 × 40
	Feet.	Feet.	Feet.	Feet.
Length of bucket frames	65	72	76	80
	Cubic feet.	Cubic feet.	Cubic feet.	Cubic feet.
Capacity of buckets	9	9	9	9
When built	1866	1871	1878	1884
	£.	£.	£.	£.
Original cost	10,134	13,800	17,340	18,100

All are fitted with force pumps to raise water to the shoots, a winch on either end provided with three barrels, each working independently of the other, and fitted with differential wheels, so as to heave-in the mooring chains at either 6 feet or 12 feet per minute. There is a capstan at each end, driven from the engine, for hauling the barges alongside; also a 5-ton derrick-crane for changing buckets and bottom-tumblers.

The greatest expense incurred in repairs is for the bucket-chain. Twenty years ago buckets, pins, mouthpieces and links were made of forged or wrought iron, the principal wearing parts being laid with blister steel. The double links were riveted on to wrought-iron backs, but with the continual jarring in working, the rivets soon became loose, then the holes began to wear. If taken off in time they could be fastened with larger rivets, and so made to serve a little longer, but very soon new backs had to be put on.

These repairs being all smith-work were very expensive, and renewals had to be effected every four months. Sixteen years ago the Author made trial of cast-steel backs, having the links cast on. Some difficulty was experienced at first in obtaining the castings sound; but by perseverance this difficulty was overcome, and they are now supplied perfectly sound. Cast-steel pins were then tried, next single links, and lastly cast-steel mouthpieces. The mouthpieces are delivered flat from the works, and are guaranteed to bend to the required shape, which, if they do, they will stand the work without breaking.

The buckets are put together at the Commissioners' shops, and have about 9 cubic feet capacity. The eyes of the backs are cast of a size to admit a cast-steel pin, smoothed with an emery wheel, and worked until worn large enough to admit of bushing with as little boring as possible; they are then bored out, and turned bushes fitted in. Pins and bushes wear on the pulling side; the pins are allowed to remain until worn out; but the bushes are taken out and turned; with this they last about four months.

The tumblers are also of cast steel; the lower tumbler is six-sided, the top tumbler four-sided, each cast in one piece; the lower tumbler has cast-iron "noggs" on the middle of each side to keep the buckets in place.

When the Commissioners resolved on procuring a second dredger, it was evident that the greater part of the dredgings would have to be deposited at sea. The question had therefore to be considered how this could best be done. Had the financial position of the Commissioners at the time been such as to enable them to expend a larger sum on dredging plant, steam-hopper barges would have been recommended by the Author; but as a sufficient number of hopper barges, to work one dredge could be got for half the money, and as the towage could be done by hire, it was resolved, under the circumstances, to begin with ordinary barges. Subsequent experience and investigation at different times has not enabled the Author to recommend a departure from the system then adopted.

The barges are built of iron, and at first were designed to carry 200 tons; but afterwards they were enlarged to carry 300 tons. The general dimensions are: extreme length, 89 feet; breadth, 27½ feet; depth, 11 feet. The capacity of the hopper is 5,500 cubic feet, or rather more than 200 cubic yards. There are six doors, three on each side, hinged on the kelson, the size of each door being 8½ feet by 6 feet. Six barges built during 1883 have cost, including all fittings and superintendence, £2,240 each; but at the present time, January 1884, they could be got for £1,800. From six to eight, according to the distance from the discharging ground, are required to keep each dredger at full work.

As already stated, the steam-tugs were at first hired, but the Commissioners have now five of their own, and a sixth building. They also employ two, or sometimes three, on hire; these vary in size from 30 to 50 HP. nominal. The medium between these sizes is economical. The accounts relating to the steam-tugs are kept separate from those belonging to the dredgers account; the work done by the Commissioners' boats is charged to dredging at the same rate as is paid for boats on hire, and is sufficient to cover interest and renewals.

The dredgings are discharged into the sea 3 miles beyond the bar. When working within 7 or 8 miles of the discharging ground, one of the larger boats can keep a dredger supplied with barges. From 8 to 11 miles, two boats are required; these make two journeys to sea, and take two barges each time, or an average of four barges per day when at regular work.

The distance between Stockton bridge and the bar is 12 miles. The dredging operations, however, have as yet only extended over 9½ miles, of which at first two-thirds of the bed of the river was of sand or silt, and one-third clay and stones. The clay was reached at a depth of from 7 to 9 feet below low water over the greater part of the river, except about 2 miles in front of Middlesbro', and in the second cut. The character of the clay varies from soft plastic to very hard and dry; and in all cases boulders are met with; but they are more numerous in the hard ground. Numbers of them are sometimes found together in pockets; their general weight is from 5 cwt. to 1 ton, but they often attain 4 tons, and one boulder was lifted weighing more than 7 tons. A great many of the smaller stones are brought up by the buckets, but the larger ones are pushed to the side of the cutting, and are lifted by divers.

A large quantity of oak trees have also been met with, partially embedded in the clay, but in holes or depressions, and in numbers together. No. 2 dredger, in the autumn of 1883, in four weeks exposed one hundred and thirty-four trees, varying in length from 12 to 60 feet, and from 15 inches to 5½ feet in diameter. They nearly all lie with their roots up stream.

The dredgers are not worked double shift, but the crews being paid according to the amount of work done, the hours of labour extend generally over all the daylight, and in summer up to sixteen hours per day. A certain quantity, varying according to the character of the material, is considered a week's work, and all above that quantity is paid for *pro râta*, and divided amongst the men according to their rating. In this arrangement the men on the hoppers and also the steamboat men participate. All are thereby interested in pushing on the operations. The tonnage-rate includes the time occupied in changing buckets, pins, and links; but should delay arise through break-down, or accident, a corresponding reduction is made in the weekly quantity required.

APPENDICES.

TEES CONSERVANCY.

I.—Cost of One Dredger Bucket, complete, with Two Links and Four Pins.

	£.	s.	d.	Cwt.	qrs.	lbs.	£.	s.	d.	Per cent. Less
1 cast-steel bucket back . . .	1	5	0	7	3	23	9	14	0	2½
1 „ mouthpiece . . .	1	5	0	1	0	22	1	9	0	„
1 wrought-iron body	0	6	6	1	1	1	0	8	1	„
1 rolled-steel bottom	0	7	0	0	1	16	0	2	11	„
62 B.B. rivets for do.	0	10	6	0	0	18	0	1	8	„
Labour fitting above, and use of tools		..			..		1	10	10	..
2 cast-steel single links . . .	1	5	0	2	3	0	3	7	1	2½
4 „ bushes for do. . .	1	17	4	0	0	21	0	6	10	„
Labour, boring links, turning and boring bushes and fitting complete		..			..		0	3	5	..
4 cast-steel pins	2	0	0	0	1	24	0	18	1	2½
4 wrought-iron forelocks . . .		..			..		0	0	6	..
							18	2	5	

There are forty buckets on a single ladder.

II.—Statement of Cost of Dredging, Labour, and Maintenance, for Three Years ending 31st October, 1883.

——	No. 2.			No. 3.			No. 4.		
Wages—Dredger crew	2,477	16	0	2,459	9	10	2,738	15	2
„ Hoppermen	2,641	16	6	2,457	17	3	2,961	12	5
Coals	993	6	4	886	3	9	981	14	9
Towage	7,153	16	5	6,917	16	9	8,223	16	0
Repairs to dredgers, hoppers, and coal craft	2,542	3	0	4,858	1	11	3,489	3	7
Rope, oil, tallow, and sundries . .	633	18	8	700	3	10	635	15	4
Damages paid	24	19	5	167	13	6	351	1	9
Proportion of diver and crew . .	202	0	0	131	4	4	131	4	4
Insurance	30	0	0	45	0	0	60	0	0
Total cost	16,699	16	4	18,623	11	2	19,573	3	4

	Quantity Dredged. Tons.	Cost per Ton. d.
No. 2 dredger	1,262,485	3·17
No. 3 „	1,553,375	2·84
No. 4 „	2,035,525	2·30

10,000 tons of clay is considered a week's work.

The expense of coaling, and the wages of a superintendent and timekeeper, are included in the wages of a dredger crew.

There are nine men on each dredger, paid as under, exclusive of overtime:—

	Per Day.		Per Week.		
	s.	d.	£.	s.	d.
Master	5	10	1	15	0
Engineer	5	10	1	15	0
Fireman	4	0	1	4	0
Foreman	4	0	1	4	0
Four deckmen each	3	6	4	4	0
Cook	3	0	0	18	0
Night watching	..		0	12	3
Six hoppermen, each	4	0	7	4	0
" "	3	10	6	18	0
Proportion of coaling and superintendence			1	18	0
			27	12	3

III.—STATEMENT of QUANTITY and QUALITY of MATERIAL DREDGED by each DREDGER, and the AVERAGE DISTANCE TOWED to DEPOSIT GROUND, for THREE YEARS ENDING 31st OCTOBER, 1883.

Average Distance Towed.	No. 2.		No. 3.		No. 4.	
	Tonnage.	Quality.	Tonnage.	Quality.	Tonnage.	Quality.
Miles.						
7	369,640	Sand, clay, and slag.	93,040	Sand, clay, and silt.	825,335	Sand and clay.
8	..	..	..	..	275,525	Sand and silt.
9	104,080	Sand and silt.	146,780	Sand and silt.	303,475	Sand, clay and silt.
10	102,985	Sand, clay, and silt.	879,595	Sand, clay, and silt.	492,460	Sand, clay, and stones.
11	102,775	Silt and clay.	60,880	Clay and stones.	138,730	Sand, clay, and silt.
12	294,570	Sand and silt.	373,080	Sand and silt.		
13	217,480	Clay, stones, and trees.				
14	70,955	Clay.				
	1,262,485		1,553,375		2,035,525	

No. 2 dredger was employed about one-half of the time dredging at wharves. where frequently only one ladder could be used.

(*Paper No. 1975.*)

"Some Particulars of an Artesian Well Bored through the Oolitic Rocks at Bourn, Lincolnshire, in 1856."

By JAMES PILBROW, M. Inst. C.E.

THE subject of artesian-wells is not without interest to the engineer, whose attention is chiefly directed to the supply of towns and other places with water. For this reason, the description of a small but productive artesian-well, completed at Bourn in Lincolnshire in 1856, is presented. The well was intended to supply the town of Bourn with water, the undertaking being in the hands of a small joint-stock company. The town had been until then, without any public supply, and almost without a private one. The wells were shallow, as in most of the towns in that part of the county; but many houses were wholly dependent upon carts, which fetched water from a considerable distance. These circumstances gave increased importance to the fact of such a supply being found under the site of the place.

The boring, 4 inches in diameter, passed through several oolitic strata, to a depth of 92 feet. Below the alluvial soil and gravel, a hard shelly limestone, 32 feet in thickness, was encountered. The bore-hole here was made slightly conical to admit of the taper end of a cast-iron pipe being inserted and driven tightly, to exclude any surface-water, and to prevent water from the bore escaping into the gravel, and thus lose its full power to rise above the surface. The boring was then continued, through various beds, till it reached a stratum, 6 feet thick, of compact and hard rock, in passing through which, at 92 feet below the surface, the tool fell suddenly about 2 feet, evidently into a chasm or hollow, striking upon the hard surface of the underlying rock. The water immediately rushed up with great force, and drove the men from their work; and it was not without difficulty that the joints for attaching the curved pipe and sluice-valve at the surface could be accomplished.

The site of the town of Bourn partakes of the ordinary character of the county, and is flat; the highest part, where the well is situated, being only about 6 feet above the general level. It had been the intention of the Author, should the water rise with sufficient force, as he believed it would do, to supply the town direct from the boring, and in this way the work was carried out, the flow and pressure having proved even greater than was anticipated.

An air-chamber was fixed at the well to regulate the pressure, and to equalise the supply of water to the town. The water rose at the Town Hall exactly 39 feet 9 inches above the ground. The yield at the bore and surface-level, ascertained by filling a tank capable of containing 5,000 gallons, was at the rate of 567,000 gallons per day, and there was no diminution on letting the whole run continuously to waste. The yield was also tested by a "notch-board," which, by using the coefficient 0·563, and measuring at still-water and not at the "crest," gave 575,201·8 gallons.

The Author knows of no other boring of like dimensions, either in this country or on the Continent, which yields so large a quantity of water, or where, the boring being made on the general level of the surrounding district, the water from which flows to so great a height above the ground.

It is needless to say that the town of Bourn has since enjoyed an unlimited supply of pure water without the assistance of engine, pumps, or reservoirs, and in far greater quantity than it requires. The town of Spalding, several miles distant, has subsequently been supplied from the same source, the water being conveyed by pipes laid under the turnpike road.

The water-mains were laid under every street, with fire-cocks at intervals, and it was satisfactory to all, and surprising to some, to see the water thrown upon the roofs of houses by a hose and jet-pipe, as from a fire-engine, and that only by the natural pressure of the spring.

The water, by Professor Brand's test, gave 19·4 degrees of hardness, arising chiefly from the presence of bi-carbonate of lime; but by boiling it is rendered much softer.

(*Paper No. 1976.*)

"On the Theory of the Dynamo-Electric Machine."[1]

By RUDOLPH JOSEPH EMANUEL CLAUSIUS, Hon. M. Inst. C.E.

(Translated and Abstracted by PAGET HIGGS, LL.D.)

DYNAMO-ELECTRIC machines, like the steam-engine in its time, are receiving practical development from their theoretical consideration, and it has been attempted, in their present condition of progress, to demonstrate mathematical formulas relating to them. But until now these formulas, as applied, do not appear to the Author entirely to correspond to the object, as they either rest on theoretically defective bases or are too imperfect to refer to all the circumstances involved. The Author therefore communicates a somewhat comprehensive theoretical development.

1. *Essential constituents of the dynamo-electric machine.*—Dynamo machines, as hitherto constructed, have outwardly many forms, but in principle they deviate little from one another, and the Author believes that amongst the continuous current machines the forms of Gramme and Siemens are to be regarded as types. Even these are so similar to one another in their effect that they, so far as concerns the origin of the basic formulas, need not be separately studied.

To the essential constituents belongs, in the first place, a fixed electro-magnet with large polar surfaces, or a combination of several fixed electro-magnets, whose similar poles are united by iron pieces into a common polar surface. Between the polar surfaces of the fixed electro-magnet there is a space occupied by the rotating electro-magnet, the two constituents of which, the winding and the iron core, may be separately studied. The former, for which rotation is necessary, is termed the rotary helix; and the latter, the rotation of which is not essential, its iron core. The rotating helix is in many divisions, and these are in conductive

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[1] The original article appeared in Wiedemann's "Annalen der Physik und Chemie," New Series, vol. xx., 1883, pp. 353–390; since this abridgment was in type, a full translation has appeared in the "Philosophical Magazine" for January and February 1884, pp. 46, 119, and is also appearing in "The Electrician."

connection, so that the end of one and the beginning of the following division are always connected together, and with a metal strip. These metal strips are so fixed next to one another as together to form a cylinder, which rotates with the helix, and upon which rub or glide the two contact-brushes that form the beginning and the end of that conducting part which is wound around the fixed electro-magnets, and including the external conductor. The rotating helix in each of its positions is divided into two halves by the electric currents which go from the one contact-brush and meet again in the other contact-brush.

The iron core of the rotating helix is magnetised in a double manner. It forms between the poles of the fixed electro-magnet a connecting armature, but which is not in contact, and obtains therefore a magnetisation of such a kind that to every pole of the fixed electro-magnet is directed an opposite pole of the iron core. To express this briefly, it may be said that the axis of magnetisation produced in the iron core has the opposite direction to the axis of the fixed electro-magnet. On the other hand, the iron core is magnetised by the electric current flowing through the windings of the rotating helix from the one contact-brush to the other. The contact-brushes are so placed that the axis of the magnetisation produced by this cause is vertical to that axis produced by the first. From the junction of these effects a magnetisation results whose axis has an irregular direction between these directions. When the iron core is revolved, its poles maintain a fixed position in space, whilst they change continually their position in the iron core.

The inductive effect occurring in the helix during its rotation is threefold. In the first place, the fixed electro-magnet acts inductively on the rotating helix. In the second, there is the inductive polar effect due to the magnetisation of the iron core by the convolutions of the helix itself. Thirdly, the convolutions interact inductively the one upon the other to some slight extent.

2. *Law of Induction.*—The rotating helix and the helices of the fixed magnets consist of many convolutions, and these lie so close together that for every single convolution, and every joined group of convolutions, it is indifferent whether it be considered as having its end connected with its own beginning, instead of with the beginning of the following convolution or group. The helices may therefore be regarded as a system of closed circuits. The magnetisation of the mass of iron may be considered due to the existence of innumerable small closed electrical circuits in its

mass, so that there only remain to be studied the effects of closed electrical currents upon closed electrical circuits. The representation of the law of induction becomes very simple. Let any system of closed currents be given, flowing in the circuits s, s_1, s_2, &c., and having quantities i, i_1, i_2, &c., and, further, a closed circuit σ, in which flows the unit current. Understanding by $d\,s$ any element of some one of the circuits s, s_1, s_2, &c., and by $d\,\sigma$ an element of the circuit σ, and designating by $(s\,\sigma)$ the angle between the directions of both elements, and their reciprocal distance by r, the electro-dynamic potential W of the given current system in the circuit σ, and of unit quantity, is represented by the equation

$$(1.)\quad W = \int\!\!\int \frac{i \cos(s\,\sigma)}{r}\, d\,s\, d\,\sigma,$$

where the one integration is over the series of circuits s, s_1, s_2, &c., and the other over the circuit σ. In this expression for W the current-quantities are supposed taken in electro-dynamic or electro-magnetic absolute measures. If electro-static measures are adopted, the expression must be divided by K^2 where K is the critical velocity of electricity, about 30 meridian-quadrants.

When any one movement of the circuit, and at the same time an alteration of the current-quantities i, i_1, i_2, &c., occur, the induced electromotive force e in the circuit σ is estimated by the equation

$$(2.)\quad e = -\frac{d\,W}{d\,t},$$

in which t is time.

3. *Application of the equation to the rotating helix.*—Whilst the foregoing equation is applied to the electromotive force induced in the rotating helix, in consequence of its movement, there may be studied some one of the divisions into which the helix is divided as representing the circuit σ. Following this division of the circuit during an entire revolution, there occurs a series of changes until the circuit assumes its first position; so that the final value of W is equal to its initial value. But the direction in which the electromotive force is to be calculated as positive does not hold good in the whole helix to an equal degree, there being a difference in the two halves, as is perceived when it is considered that the current flows from one contact-brush through the two halves to the other contact-brush. Thus, also, for every single division of the helix the direction regarded as positive changes at every half-revolution. As the induced effect during both halves

of the revolution is equal, it is necessary to consider only one-half revolution. At the beginning of this half-revolution, for the time t', W may have the value W', and at the end, or at the time $t' + \frac{1}{2}\tau$ [where τ signifies the rotation-time], W may have the value W'', then the mean electromotive force (2) is obtained from

$$(3.)\quad \frac{1}{\frac{1}{2}\tau}\int_{t'}^{t+\frac{1}{2}\tau} e\,d\,t = -\frac{1}{\frac{1}{2}\tau}\int^{t'+\frac{1}{2}\tau}\frac{d\,W}{d\,t}\,d\,t = \frac{1}{\frac{1}{2}\tau}(W' - W'').$$

From this expression for a single division of the helix, that for the whole helix may be obtained by multiplication by the number of divisions. To determine this number it must be remarked that the induced force on both halves of the rotating helix is not to be taken as a sum, since these halves are not in sequence, but lie parallel to one another. E_1, or the whole electromotive force becomes,

$$(4.)\quad = \frac{n}{\tau}(W' - W'').$$

If, instead of the rotation time τ, the number of revolutions in the unit of time v is used,

$$(5.)\quad v = \frac{1}{\tau},$$

and (4) becomes

$$(6.)\quad E_1 = n\,(W' - W'')\,v.$$

4. *Retro-action of the moving circuit on the fixed.*—In the previous paragraph there has only been studied the electromotive force due to the magnetisation of the iron core and the current in the fixed circuit. It may now be asked whether the existing current in the moved circuit induces an electromotive force in the fixed circuit. The Author again selects for examination a single division of the moved circuit, also designated by σ. The current flowing through it is represented by j, and twice changes its direction in each revolution. The fixed circuit is supposed to be traversed by the unit current, and causes the electro-dynamic potential of σ upon s, represented by Ω, and by an expression of similar form to equation (1),

$$\Omega = \int\int j\,\frac{\cos(s\,\sigma)}{r}\,d\,s\,d\,\sigma.$$

With the help of this quantity the induced electromotive force ϵ

in the fixed circuit, at the time t, can be determined by the following equation, corresponding to (2):

$$\epsilon = \frac{d\,\Omega}{d\,t}.$$

To determine from this the mean electromotive force there must be an integration for the time, and the integral divided by the time. As the positive direction of the electromotive force is unchanged, the integration may be extended over the whole time of rotation τ,

$$\frac{1}{\tau}\int_{t'}^{t'+\tau} e\,d\,t = -\frac{1}{\tau}\int^{t'+\tau}\frac{d\,\Omega}{d\,t}\,d\,t = \frac{1}{\tau}(\Omega' - \Omega''),$$

where Ω' is the initial, and Ω'' the final, values of a rotation. Now, after an entire rotation, the position of the division of the circuit, as also the direction of the current, are the same as at the commencement of the revolution; from which it follows that Ω'' equals Ω', and, consequently, the above expression is equal to nil. This holds good for all the divisions of the moved conductor; hence the result that *in the fixed circuit no electromotive force is induced.*

5. *Inductive influence of the moved circuit upon itself.*—In this respect it is to be observed that the circuit involved, namely, the rotating helix, is only wholly moved so that every two parts maintain unchanged their relative positions. It therefore follows that motion does not set up any reciprocal induction. There requires thus to be taken into account only the change or reversal of current as productive of induction effects. This subject has already been treated by Joubert and by Maxwell, and the Author agrees with their views and explanations although not with the method of calculation. The Author determines that in consequence of the position of the contact-brushes and of the movement of the helix the induced electromotive forces on both sides are not produced complete, but that there remains a surplus on one side, which, like the electromotive force from the self-induction, is opposed to the direction of the current. The evaluation of this difference depends on the construction of the machine, and the Author is content with an expression including an undetermined factor and with an explanatory remark, his reasoning leading to the equation

$$(8.)\quad \mathrm{E} = n\,(\mathrm{W}' - \mathrm{W}'')\,v - \rho\,i\,v,$$

where ρ, the only quantity remaining unexplained, represents the undetermined factor.

6. *Work performed by the electromotive and ponderomotive forces.*—In order to express the work performed in the unit of time by the previously determined electromotive force E, this quantity must be multiplied by the quantity of current i which flows through both halves of the rotating helix. Therefrom

$$(9.)\quad E\,i = n\,(W' - W'')\,i\,v - \rho\,i^2\,v.$$

This work can be compared with another work. The winding through which the current is passing is affected by the other current systems, to which also the magnets belong, or by a "ponderomotive" force, and its work is determined to be in unit time

$$(10.)\quad T = n\,(W'' - W')\,i\,v.$$

If this work be compared with that of (9) the electromotive force, it differs from the latter by the term $-\rho\,i^2\,v$. And there can be written

$$(11.)\quad E\,i = -T - \rho\,i^2\,v.$$

7. *Estimation of the magnetism of the electro-magnets in dynamo-electric machines.*—To give the previous theoretical results more approximate forms for further calculation, there must be expressions constructed for the strength of the electro-magnets. In the fixed electro-magnets, the magnetic moment is not proportional to the quantity of the current, but follows another law. With smaller quantities of current it increases nearly proportionally to the quantity; with greater quantity of current it increases more slowly and approaches a limit. Frölich employs an equation, of which the following is an unessential modification:—

$$(12.)\quad M = \frac{A\,i}{1 + a\,i},$$

where M is the magnetic moment, and A a, constants. The Author does not believe that this represents the proportion in the best manner, but its adoption is advisable on account of its simplicity.

With very small quantities of current the "permanent" magnetism of the iron of the electro-magnets from previous magnetisation must be taken into consideration. But this, except in special points concerned with the starting of the current is of no importance.

It is, however, necessary to study the magnetisation of the iron core of the rotating helix, which presents complications because it ori[illegible] has been observed, from two magnetising forces, that of the fixed magnet and that of the current flowing through the helix. The first force is proportional to the magnetic moment M of the fixed magnet, and would produce a corresponding momentum in the core, if it operated alone, and, as influenced by i, the current flowing through the fixed magnet is represented by

$$\frac{C\,M}{1 + y\,M}$$

where C and y are constants. The second force is vertical to the first, but may be represented, in substituting N for M and considered as acting alone, by

$$\frac{C\,N}{1 + y\,N}.$$

The quantity N must manifestly be proportional to the quantity of current i passing in the rotating helix, so that

$$(13.)\quad N = B\,i$$

where B is a constant for each machine. The resultant of the two forces M and N acting together will be $P = \frac{C\sqrt{M^2 + N^2}}{1 + y\sqrt{M^2 + N^2}}$, but as the radical term in the denominator is inconvenient, it may be modified by substituting for the radical a quantity proportional to the current-strength, and without lessening the degree of accuracy

$$(14.)\quad P = \frac{C\sqrt{M^2 + N^2}}{1 + \beta\,i}$$

where β is a new constant determined for each machine.

The axis of this magnetic moment P has the same direction as the other resultants. If these axes make angles ϕ and $\frac{\pi}{2} - \phi$, ϕ may be determined from the equations

$$(15.)\quad \cos\phi = \frac{M}{\sqrt{M^2 + N^2}};\ \sin\phi = \frac{N}{\sqrt{M^2 + N^2}}.$$

By these equations the magnetic moment P can be resolved into two components:

$$(16.)\quad \begin{cases} P_1 = P\cos\phi = \dfrac{C\,M}{1 + \beta\,i}; \\ P_2 = P\sin\phi = \dfrac{C\,N}{1 + \beta\,i}. \end{cases}$$

8. *Work of the ponderomotive and electromotive forces in the case where the iron core of the rotary helix is at rest.*—After the available magnetic moments are expressed, the work done by the ponderomotive force can be determined. When the iron core of the rotating helix is fixed, the helix is subject to a double force, that of the fixed magnet operating from without and that of the magnetic iron core operating from within. The ponderomotive force which the fixed electro-magnet exercises upon the current-energised rotating helix, is proportional to the magnetic moment M of the fixed electro-magnet, and as well to the magnetic moment of the current-energised helix, and to the previously noticed quantity N. The work due to the ponderomotive force is

$$-h\,M\,N\,v.$$

where $-h$ is a constant indicating the negative character of this force. The other ponderomotive force which the rotating helix experiences from its magnetic iron core is also proportional to the quantity N, and further depends upon the magnetic moment of the iron core. In this magnetic moment must be distinguished the two components previously cited. The component P_2 has no working moment on the rotating helix. The component P_1, whose axis is vertical to the axis of N, gives a moment proportional to P_1. Therefore this latter ponderomotive force is represented by

$$-K\,N\,P_1\,v.$$

By addition, can be obtained the whole ponderomotive force during work performed in the unit of time

$$(17.)\quad T = -h\,M\,N\,v - K\,N\,P_1\,v.$$

From this work of the ponderomotive force the work of the electromotive force is immediately derived with the help of equation (11),

$$(18.)\quad E\,i = h\,M\,N\,v + k\,N\,P_1\,v - \rho\,i^2\,v.$$

Substituting the foregoing values for P_1

$$(19.)\quad T = -M\,N\left(h + \frac{k\,C}{1+\beta\,i}\right)v.$$

$$(20.)\quad E\,i = M\,N\left(h + \frac{k\,C}{1+\beta\,i}\right)v - \rho\,i^2\,v.$$

9. *Work of the ponderomotive and electromotive forces for the case where the iron core participates in the rotation of the helix.*—

In this case, although the individual convolutions of the helix maintain, during the common movement, their positions relatively to the parts of the iron, their positions relatively to the poles are continuously changed. With slow rotation it may be assumed that the poles of the iron core have the same position in space and the same strength as in an iron core at rest. With quicker rotation this is certainly not the case, and there occur deviations according to the position and strength of the poles. If it be assumed that in the rotating iron core the poles have the same position in space and the same strength as in an iron core at rest, equations (18) and (20) will apply. As to the work performed by the ponderomotive force the conditions are not so simple, but the Author makes intercomparison by assuming that the iron core only is rotary whilst the helix is maintained fixed. If now the iron core is made magnetic by the common effect of the fixed electro-magnet and the current passing in the helix, motion in the core will not occur, as might be concluded, showing that the rotary moment exercised by the fixed electro-magnet upon the iron core is equal to the rotary moment exercised by the iron core upon the helix, and is similarly directed. Consequently, the works have the same value when the iron core rotates with the helix as when the iron core is at rest.

10. *Modification of the previous results under quick rotation.*—The results with quick rotation are affected by the sluggishness of the iron in reference to changes of its magnetic condition, so that the poles in the rotating iron core have a somewhat different position in space and somewhat different strength. This condition has not hitherto, the Author believes, been taken into account. That which next concerns the position of the poles, and therefore the direction of the magnetic axis is (section 7) the angle ϕ formed by the magnetic axis of the iron core with the counter direction of the axis of the fixed electro-magnet, determined by the equations (15). If the iron core is rotated quickly it may be assumed that the magnetic axis is displaced through a small angle in the direction of the rotation, and that the angle is proportional to the velocity of rotation. If ϕ^1 represents the angle which the altered magnetic axis of the iron core forms with the counter direction of the axis of the fixed electro-magnet, there may be written

$$(21.)\quad \phi' = \phi + \epsilon v,$$

where ϵ is a small constant.

As to the strength of the poles, this must be somewhat less in a rotating iron core than in an iron core at rest. The Author thinks no serious error will be committed if it be assumed that the altered magnetic moment is as great as that of the changed axial direction of the components of P in equation (14). Consequently, the existing magnetic moment of the rotating iron core may be put as

$$(22.)\quad P' = P \cos \epsilon v.$$

The Author then derives by similar reasoning as previously the components

$$(23.)\quad \begin{cases} P_1' = \dfrac{C}{1+\beta i}(M - \epsilon v N) \\ P_2' = \dfrac{C}{1+\beta i}(N + \epsilon v M). \end{cases}$$

The magnetic sluggishness of the rotating iron core has, under all circumstances, prejudicial effect upon the capacity for work of the machine. This influence is somewhat diminished by giving to the contact-brushes another position for quicker rotation. Besides the retarding effect of the magnetic sluggishness of the iron core, there may be also the induction of currents in the mass of the iron core itself. These currents, as well as other inductive effects of a more remote character pointed out by the Author, are removable by separating the iron core into parts; or instead of employing a massive iron ring, by substituting a ring composed of iron wires. Where these currents are found in important measure, their effect is doubled. In the first place, the currents themselves have a magnetic moment; also they exercise a magnetic effect upon the iron, and alter the magnetism of the iron core. Their magnetic moment is expressed by the product $\eta v \sqrt{M^2 + N^2}$, where η is a small constant. This product, multiplied by D (a constant corresponding to and substituted for C), and made the numerator of the fraction in equation (14), will give the magnetic moment corresponding to P. As both of these moments have the same axial direction, they may be added, and the moment $\eta v \sqrt{M^2 + N^2}\left(1 + \dfrac{D}{1+\beta i}\right)$, obtained.

The value of the components of the entire existing magnetic moments in the iron core may be put

$$(24.)\quad \begin{cases} P_1'' = \dfrac{C}{1+\beta i}(M - \epsilon v N) - \eta v N\left(1 + \dfrac{D}{1+\beta i}\right). \\ P_2'' = \dfrac{C}{1+\beta i}(N + \epsilon v M) + \eta v M\left(1 + \dfrac{D}{1+\beta i}\right). \end{cases}$$

For brevity, ϵ' being introduced with the signification

$$(25.)\quad \epsilon' = \epsilon + \frac{D}{C}\eta,$$

the equations become

$$(26.)\quad \begin{cases} P_1'' = \dfrac{C}{1+\beta i}(M - \epsilon' v N) - \eta v N, \\ P_2'' = \dfrac{C}{1+\beta i}(N + \epsilon' v M) + \eta v M, \end{cases}$$

and are more general than (23). For those machines in which these induced currents in the iron are too unimportant for consideration, it is only required to put $\eta = o$, and consequently $\epsilon = \epsilon'$, to obtain equation (23).

11. *Application of the foregoing values to determine the work done by the ponderomotive force and by the electromotive force.*—Returning to equations (17) and (18), and substituting for the quantities P_1 and P_2, the adjusted values P_1'' and P_2''

$$(27.)\quad \begin{cases} T = -hMNv - kMP_2''v \\ Ei = hMNv + kNP_1''v - \rho i^2 v. \end{cases}$$

Further, putting for P_1'' and P_2'' the values of (26)

$$(28.)\quad \begin{cases} T = -MN\left(h + \dfrac{kC}{1+\beta i}\right)v - kM^2\left(\eta + \dfrac{\epsilon' C}{1+\beta i}\right)v^2 \\ Ei = MN\left(h + \dfrac{kC}{1+\beta i}\right)v - \rho i^2 v - kN^2\left(\eta + \dfrac{\epsilon' C}{1+\beta i}\right)v^2. \end{cases}$$

Into these equations finally there are to be introduced the values for M and N as by (12) and (13) to obtain (29).

$$(I.)\quad T = -\left[\frac{AB}{1+ai}\left(h + \frac{kC}{1+\beta i}\right)v + \frac{kA^2}{(1+ai)^2}\left(\eta + \frac{\epsilon' C}{1+\beta i}\right)v^2\right]i^2.$$

$$(II.)\quad E = \left[\frac{AB}{1+ai}\left(h + \frac{kC}{1+\beta i}\right)v - \rho v - kB^2\left(\eta + \frac{\epsilon' C}{1+\beta i}\right)v^2\right]i.$$

These equations are fundamental to all further calculation.

To bring these equations under convenient control, the following substitutions may be made—

$$(30.)\quad \left\{ \begin{array}{ll} a = \dfrac{1}{\alpha} & l = \dfrac{A}{B\,\alpha} \\ b = \dfrac{1}{\beta} & \sigma = k\,B^2\,\eta \\ p = \dfrac{h\,A\,B}{\alpha} & \\ q = \dfrac{k\,A\,B\,C}{\alpha\,\beta} & \lambda = \dfrac{k\,B^2\,C\,\epsilon'}{\beta} \end{array} \right.$$

These are applied to the preceding two equations.

12. *Determination of the current quantity produced by a machine when no foreign electromotive force is co-exerted.*—When the external circuit is closed and contains no foreign electromotive force, $E = R\,i$, and [with the substitutions (30)] II. becomes

$$(31.)\quad R\,i = \left[\frac{1}{a+i}\left(p + \frac{q}{b+i}\right)v - \rho\,v - \left(\sigma + \frac{\lambda}{b+i}\right)v^2\right]i,$$

reduced to (by dividing by i, &c.)

$$(32.)\quad 1 = \frac{1}{a+i}\left(p + \frac{q}{b+i}\right)\frac{v}{R+\rho\,v+\sigma\,v^2} - \frac{\lambda}{b+i}\,\frac{v^2}{R+\rho\,v+\sigma\,v}$$

Substituting

$$(33.)\quad w = \frac{v}{R+\rho\,v+\sigma\,v^2}$$

there obtains

$$(34.)\quad 1 = \frac{1}{a+i}\left(p + \frac{q}{b+i}\right)w - \frac{\lambda}{b+i}\,v\,w.$$

From this equation can be immediately determined the quantity i of the current produced by the machine.

Multiplying this equation by $a + i$ and by $b + i$, and arranging according to the powers of i,

$$(35.)\quad i^2 - (p\,w - \lambda\,v\,w - a - b)\,i - (p\,b + q)\,w + \lambda\,a\,v\,w + a\,b = o,$$

and solving the quadratic equation

$$(36.)\quad \left\{ \begin{array}{l} i = \tfrac{1}{2}\,(p\,w - \lambda\,v\,w - a - b) \\ \pm\,\tfrac{1}{2}\sqrt{(p\,w - \lambda\,v\,w - a - b)^2 + 4\,(p\,b + q)\,w - 4\,\lambda\,a\,v\,w - 4\,a\,b} \end{array} \right. .$$

Of the two signs before the root sign only the upper is applicable, and the following form can be given to the equation (36)—

$$(37.)\quad \begin{array}{l} i = \tfrac{1}{2}\,(p\,w - \lambda\,v\,w - a - b) \\ +\,\tfrac{1}{2}\sqrt{(p\,w - \lambda\,v\,w + a - b)^2 + 4\,(q - p\,a + p\,b)\,w} \end{array}.$$

Again, substituting for simplification,

$$(38.) \qquad w' = w\left(1 - \frac{\lambda}{p} v\right) = \frac{v - \frac{\lambda}{p} v^2}{\mathrm{R} + \rho v + \sigma v^2}.$$

$$(39.) \qquad c = q - p a + p b,$$

the equation assumes the following very comprehensive form—

$$(40.) \; i = \tfrac{1}{2} (p w' - a - b) + \tfrac{1}{2} \sqrt{(p w' + a - b)^2 + 4 c w}.$$

13. *Starting of the machine.*—The Author shows that for equation (36), with nil values for v, there is given a negative value for i, which must not be taken as meaning that the initial equation (II.) gives unsatisfactory results for small rotary velocities; for in this case the machine gives no current until a certain velocity is attained, which agrees with practical observation. To deal strictly with this point, there must be taken into consideration the "remanent" magnetism of the iron of the electro-magnets. The equation (12) for the magnetic momentum of the fixed electro-magnet gives, for $i = o$, $\mathrm{M} = o$. If now, however, a certain magnetisation is already present in the iron before the introduction of the current, this must naturally be taken into account in the determination of the existing magnetisation with a weak current. An approximation may be obtained by supposing μ the small moment of the "remanent" magnetisation, and then there is to be determined the value of i, for which the expression for M has the value μ.

Therefore put $\mu = \dfrac{\mathrm{A}\, i_1}{1 + a\, i_1}$

whence it follows

$$(42.) \qquad i_1 = \frac{\mu}{\mathrm{A} - a\mu},$$

where i_1 is the relative value of i. And according to this determination there holds for all values of i that are less than i_1, the equation $\mathrm{M} = \mu$, and for all values of i greater than i_1 the equation (12) for the magnetic moment.

It may also be considered that at starting the machine is a magneto-electrical machine; and it may be asked how great is the rotary velocity at which the machine, as a dynamo-electric machine, gives the same current as a magneto-electric machine, namely, the current of quantity i_1. To determine this value v, there must be substituted in equation (40) i_1 for i. Following similar steps, there obtains, with accentuation of corresponding values,

$$(43.)\qquad (a+i_1)\,p\,w_1' + c\,w_1 = (a+i_1)\,(b+i_1).$$

In this result the values of w_1 and w_1', deduced from (33) and (38), must be introduced to determine v_1. Neglecting the factors λ and σ as of no importance at low velocities, the expression ultimately becomes

$$(44.)\qquad v_1 = \frac{(a+i_1)\,(b+i_1)\,\mathrm{R}}{p\,(a+i_1)+c-(a+i_1)\,(b+i_1)\,\rho}.$$

For ordinary practical purposes the simplification may be extended, by considering that the production of current takes its origin with a certain rotary velocity. With this view there can be determined the limit value of the velocity when μ and i_1 approach zero. Representing this limit value of v_1 by v_0,

$$(45.)\qquad v_0 = \frac{a\,b\,\mathrm{R}}{p\,a+c-a\,b\,\rho},$$

or according to (39),

$$(46.)\qquad v_0 = \frac{a\,b\,\mathrm{R}}{p\,b+q-a\,b\,\rho}.$$

This value of v_0 represents the number of the so-called "dead" revolutions.

The Author reserves further applications of these fundamental equations to the transmission of power by dynamo-electric machines to a subsequent Paper.

(*Paper No. 1977.*)

"On the Practical Results obtained from various Water-Raising Machines in Holland."[1]

By G. Cuppari.

(Translated and Abstracted by W. H. Thelwall, M. Inst. C.E.)

Towards the end of the year 1877 the Author visited Holland, and spent a year and a half in studying the hydraulic works in that country, particularly those for draining land. Having had opportunities of examining the principal works both finished and under construction, and of taking notes from various documents referring to them, he collected a large amount of information not otherwise procurable.

In the specifications for water-raising machines in Holland, a clause is inserted to the effect that the consumption of Ruhr coal is not to exceed 6·61 lbs. per HP.[2] per hour. In practice, however, there are great differences in the duty of the engines.

The Rhineland Company. Pumping-Station at Halfweg.—This station was erected for the purpose of discharging into the Y (which was converted into a canal in 1873) the waters of the general collecting basin of the great Rhineland Company. The surface of this basin (called "boezem," a Dutch word which will be used throughout the Paper) covers 8,600 acres, when the water is standing at its normal level. There discharge into this basin, naturally, the high lands, 30,443 acres in extent; artificially, the polder lands. These are classified according to the normal water-levels as follows:—

			Acres.
Normal level at	3·28 feet - A P and over		16,282
„	between 3·28 feet	and 5·0 feet—A P	60,855
„	„ 5·0	„ 6·5 „	22,314
„	„ 6·5	„ 11·5 „	0
„	„ 11·5	„ 13·1 „	3,249
„	„ 13·1	„ 14·75 „	3,874
„	„ 14·75	„ 16·4 „	66,029
„	„ 16·4	„ 18·0 „	6,731
„	„ 18·0	„ 19·7 „	7,882

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[1] The original memoir appeared in the "Ingegneria Civile e le Arti Industrielle," 1882-83.

[2] Throughout the Paper when the term HP. is used, the power is measured in water actually raised, unless otherwise stated.

These areas vary year by year in Holland, owing to the increased drying up of the land, the variations in the normal level, &c. The above are the figures for 1867, since which date there have been no changes of importance. The total area of Rhineland is 258,382 acres, but it also receives into its boezem the waters of the Woerden Association, of which the boezem area is 403 acres, and the total area draining into the boezem of Rhineland is 302,590 acres.[1]

When the lake of Haarlem, which was in communication with the boezem of Rhineland, was drained, the great diminution in the receiving basin was compensated by providing a better outlet into the North Sea at Katwijk, and three pumping-stations, at Halfweg and Spaarndam on the Y, and at Gouda on the Yssel. In 1880 another was added at Katwijk. The waters discharging into this receiving basin, composed of a network of canals and small lakes, come for the most part from the polders, that is to say, the discharge is performed mechanically. But this first lift is generally insufficient, and a second is required, which is effected by steam pumping-engines.

The internal conditions of the boezem are,

Mean water-level (1873–7)	1·656 feet - A P.
Minimum „ „	2·297 „
Maximum „ „	0·656 „
The maximum should be	1·312 „

The levels of the Y previous to its canalization were at Halfweg,

	Feet.
Mean high water	0·26 + A P.
„ low „	0·82 — A P.
Maximum high water	6·62 + A P.
Minimum low „	3·94 — A P.

After the closing of the Y, the canal which took its place was to be maintained in terms of the concession at 1·64 — AP. This level remains simply a desideratum as far as Rhineland is concerned, while during the past year the mean level of the canal at Halfweg was 1·20 — AP. The last pumping-station was intended to control the internal levels, in which the difference of a few inches might cause incalculable damage; the maximum ought never to exceed 1·31 feet — AP.

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[1] In 1881, there were discharged from the boezem 21,825 millions of cubic feet of water, of which 12,537 millions were raised by machinery; 2,684 millions cubic feet were let into the boezem, the greater part in summer to supply the canals.

The Halfweg pumping-station has six float-wheels, of a combined width of breast of 38·70 feet. The external diameter of one of the wheels is 23 feet; that of the other five, 21·33 feet. The internal radius is 5·92 feet. The floats, twenty-four in number, are inclined to the radius, so as to be tangential to a circle concentric with the wheel, and having a radius of 2·85 feet. The centre of the wheel is at 5·6 feet + AP. The steam-engine has four separate valves, with expansion regulated by hand (of the old double-acting Cornish type). The cylinder is 3·33 feet × 8·0 feet. There are three boilers always in steam, having each 538 square feet of heating surface. The maximum pressure is three atmospheres. The driving axle is connected by toothed gearing on each side to a shaft carrying three wheels. The speed is reduced in the ratio of 13·5 to 6. The wheels are all upon the same shaft, but this is not all in one piece, but in several, which can be coupled up as required.

There are three systems of construction of water-wheels, which differ in the method of transmitting the force. In the first system the force is transmitted by a driving-axle and spokes acting as struts; in the second, by a toothed wheel upon the circumference, the axle and spokes acting as struts; in the third, by a similar toothed wheel, but with a double set of rods in tension instead of spokes. The Dutch still adhere to the first system, although, according to Redtenbacher, it is not suitable when the power exceeds 10 or 12 HP. With large wheels it is very heavy. Thus the Italian wheels at Bresega, near Adria, which are on the third system, have an external diameter of 39·4 feet, an internal diameter of 26·25 feet, and a breadth of 6·56 feet. There are no larger wheels than these either in Holland or Italy. The displacement of water is about 5,300 cubic feet per minute per wheel. The axle of these wheels has a diameter at the thickest part of 1·41 foot, and 1·25 foot at the bearings. The wheels at Katwijk, which are on the first system, are only 29·5 feet in diameter, yet the axles of the furthest wheels are of the same diameter as above.

At Zeeburg, near Amsterdam, there are eight wheels of the most recent construction, of 26 feet 3 inches diameter, and 10 feet 8 inches breast. The driving-axles of the wheels furthest from the motor are 1 foot 6 inches in diameter, and weigh over 6 tons. Each wheel has four sets of spokes, each set weighing 4 tons. The driving-axles nearest the motor weigh nearly double. There are 282 cubic feet of oak, and 222 cubic feet of pine timber in each wheel. Compared to the mass and weight of material, the volume of water raised, amounting to 7,063 cubic feet per minute per wheel, seems small. The velocity of the periphery is about 208 feet per minute, which in Holland is considered moderate, but in Italy high. In this system of construction the axle is subject both to bending and torsion; in the suspension system to bending only.

Mr. Zangirolami, of Adria, constructs wheels with curved buckets capable of raising water to $\frac{4}{5}$ of the radius, giving excellent results. Instead of two toothed wheels, one at each side of the wheel, he puts one toothed wheel in the middle, thus avoiding the practical difficulty and expense of two cogged wheels of precisely similar pattern on the one hand, and the twisting effect produced by a single cogged wheel when placed at one end of the wheel on the other.

At Halfweg the driving-axle is of cast-iron, solid, 1 foot 2 inches in diameter near the motor, and 10 inches at the further end, with enlargements at the joints. The framework of each wheel is formed of three sets of spokes, which are cast in one piece with the nave and ring, or rather each set is cast in two parts and bolted together. The whole weight of one wheel with its axle is probably about 15 tons.

Tables are given of the work performed by the wheels monthly during the years 1872–5. The first Table gives the number of revolutions per minute, the number of hours worked, the volume of water raised, the lift, the effective HP., the consumption of coal in each month, and per HP. per hour. The second Table shows how the duty of the engines increases with the lift. When the lift was from 8 inches to 1 foot, the consumption of coal per HP. per hour averaged 14·20 lbs.; when the lift was from 1 foot to 1 foot 4 inches, the consumption averaged 11 lbs.; when the lift was from 1 foot 4 inches to 1 foot 8 inches, the consumption averaged 8·8 lbs.; and when the lift was from 2 feet to 2 feet 3½ inches, the consumption averaged 5·5 lbs. per HP. per hour.

This difference is accounted for by the large amount of power required simply to drive the wheels themselves. This being a constant quantity, is much greater in proportion when the work expended in raising the water is small. It would be useful to have experiments on the performance of the engines when simply turning the wheels, but, failing such experiments, the Author gives instances in which the lift was very small. On the 16th of March, 1876, with a lift of only 0·45 of a foot, all the six wheels were at work for 495 minutes, and made 2,043 revolutions, the immersion of the wheels at the time being 3·75 feet on the low-water side. Applying the recognised coefficient for similar wheels of 0·90, the volume of water raised was estimated at 30,000 cubic feet per second. The useful effect was therefore 25 HP. The total consumption of coal was 10,493 lbs., or 50 lbs. per effective HP. per hour.

General Delprat investigated experimentally the working of a somewhat similar establishment with six float-wheels for eighty days, with lifts varying from 0·033 of a foot to 1·75 foot. He found that the useful effect, when the lift was a minimum, was only 3 HP., while the work corresponding to the *vis viva* of the water issuing from the wheel was 69·24 HP. With the maximum lift, on the other hand, the former was 130·05 HP., the latter only 19·57 HP. The sum of the two kinds of work, useful effect, and work corresponding to the velocity, was 72·24 HP., with the lift of 0·033 of a foot, and 149·62 with the lift of 1·75 foot. This sum rather more than doubled, while the lift in the last case was fifty-three times that in the first, and the useful effect in water raised was about forty-three times as great.

These wheels, therefore, besides being very costly, have the disadvantage that, as the inner water-level diminishes, the discharge also diminishes, while the number of revolutions remains constant. If, then, this reduction in the inner water-level is accompanied with a reduction of the lift, the conditions of useful effect are still worse. The six wheels at Halfweg, which with an inner water-level of 8 inches – AP (the highest) give a discharge of 8,263 cubic feet per revolution, give only 5,510 when the water is at its lowest level of 2·46 feet – AP.

Hydraulic Station at Katwijk.—This was erected in 1880 to regulate more completely the waters of the Boezem. The levels of the external water are:—

	Feet.
Mean high water	2·93 + A P.
„ low „	2·72 – A P.
Maximum high water	11·48 + A P.
Minimum low „	6·56 – A P.

The distance of the buildings from the sea is 2000 feet.

This station and that at Zeeburg, near Amsterdam, intended for changing the water in the canals in that city, are the two largest of recent construction in Holland. In both the system adopted is similar to that at Halfweg. At Katwijk there are six wheels, each 29 feet 6 inches in external diameter, and 8 feet breast. The centres of the wheels are at 8 feet 3 inches above AP.; the sill of the channel is at 1·64 foot – AP., which is the mean level of the surface of the internal water. The number of wheels at work can be regulated by gearing. The weight of a single wheel with its axle is estimated at 41½ tons. The selection of this system shows that it is considered the one best adapted to the conditions at Katwijk. Flat buckets have been adopted as being the best under the conditions, namely, a lift varying daily (with respect to sea-level), and averaging from 0 to 4·5 feet, with an ordinary maximum of 6·89; the fluctuation of the internal level being very slight, the greatest difference in the year 1881 being 1·60 feet, and the greatest in a month being 0·82 feet. There is no doubt that the differences will be still smaller with the new lifting wheels at work. The manner in which the variations in internal water-level are kept within very small limits is one of the remarkable features in the Dutch system.

The buckets of the wheels at Katwijk are tangential to a circle concentric with the wheel, and having a radius of 5·25 feet. The effect of this is that with the internal water at its mean level, and the external at mean high-water level, the angle of ingress is about 20° 30′, and that of egress 42°. The proper diameter of this tangential circumference is a subject much discussed among Dutch engineers. This, together with the radius of the wheel, and the position of the axis, determines the angles of ingress and egress, upon which the effect of the wheel greatly depends. Inspector J. A. Beijerinck, the celebrated engineer of the Zuidplas and Haarlem reclamations, and the author of the first really practical project for reclaiming the Zuider-Zee, has devoted considerable attention to float-wheels and screw-elevators in a monograph on the Zuidplas, which will be referred to later on. He upholds the rule that the angles of ingress and egress of the paddles with the mean internal and external water-levels should be equal; which, when the radius of the wheel is known, readily gives that of the circumference to which the paddles are tangential, by means of a simple geometrical construction. This has long been a general practical rule, and is still frequently followed, though the desire for innovation has given rise to others, perhaps too many.

If α is the angle of ingress, β that of egress, H_i H_e the depths below the axis of the wheel of the internal and external levels, Δ the lift, R the radius of the wheel, ρ that of the above-named circumference, we have

$$H = R\left\{\sin \alpha \sqrt{1 - \frac{\rho^2}{R^2}} + \cos \alpha \frac{\rho}{R}\right\}$$

$$H = R\left\{\sin \beta \sqrt{1 - \frac{\rho^2}{R^2}} - \cos \beta \frac{\rho}{R}\right\}$$

$$\Delta = \sqrt{R^2 - \rho^2} (\sin \alpha - \sin \beta) + \rho (\cos \alpha + \cos \beta).$$

Of the quantities H_i, H_e, R, a, β, ρ, any three can be found when the other three are known, according to the theory of hydraulic wheels, by equations which correspond to the minimum for the loss of work due to various causes. This loss being expressed in terms of the remaining independent variables, including in these the velocity, which is another very important element, there will be enough equations to determine all the unknown quantities. In practice they are given by rules. One is that already given, from which $\Delta = 2\rho \cos a$. Some authorities make it a rule that the value of a shall lie between 20° and 30°. Since, if the immersion i of the buckets is known, $R = H_i + i$, the value of R depends upon that of i, which is generally between 3·25 feet, and 4·87 feet, according to the difficulties of foundations and construction. Some maintain that the ratio $\frac{\rho}{R}$ must lie between $\frac{1}{3 \cdot 5}$ and $\frac{1}{4}$. Others state that H_e must lie between $\frac{1}{7}$ and $\frac{1}{5}$ of R, but the principal rule, and that most generally adopted, is that of the equality of a and β. At Katwijk, however, this rule has not been adopted. At the maximum daily level the angle of egress is nearly double that of ingress, which is 20° 30′. At the mean level it is more favourable, increasing by about 6°. There seems very good reason for departing from the established rule.

It is true, indeed, that by improving the ingress the egress suffers, but in a very different degree. R being given, a and β can be expressed by a single variable, the angle ϕ of the paddle with the radius. The loss at the ingress will be a certain function $f_i(\phi)$, that at the egress $f_e(\phi)$, indicating by f_i and f_e two different functions. The variable ϕ will be determined by the condition that $f_i(\phi) + f_e(\phi)$ shall be a minimum. It would be difficult and almost useless to determine mathematically the expression of that sum as a function of ϕ. It is certain that for a given variation of ϕ the gain on one hand is very different from the loss on the other, and that it is better to increase the angle of egress. If this is too small, there is a useless heaping up at the discharge, which may be a very considerable part of the lift, or may even exceed it, and the rule of equal angles often places the wheels under unfavourable conditions.

The Katwijk wheels are driven by two compound engines supplied with steam from eight Lancashire boilers, with double fire-boxes, each 32·8 feet × 7·31 feet, with seven Galloway tubes. The heating-surface of each boiler is 970 square feet. It was specified that with a working pressure of 5 atmospheres the eight wheels should raise—

	Feet.
4,238,000 cubic feet per hour with a lift of	4·10
3,532,000 „ „ „	5·27
2,825,000 „ „ „	6·88

so that the maximum useful effect should be 615 HP.

On the trial of the engines, the number of revolutions varied from 3·93 to 4·54 per minute. The most convenient for ordinary working is 4, corresponding to 36 revolutions of the fly-wheel, the velocity at the periphery being 7·22 feet per second. The ratio of useful effect to indicated power varied from 33 to 70 per cent., the average being 50. It is expected that a higher value will be obtained after the engines have been in use a little while, and the gearing has become eased.

The principal dimensions of the buildings are :—

	Feet.	Ins.		Feet.	Ins.
Engine-house, inside	59	0	×	49	3
Boiler „ „	93	8	×	65	3
Each of the covered chambers for the wheels.	44	9	×	39	4
There are two chimneys 85 feet high above the fire-grates, with an internal diameter of	6	3			
Coal-store	164	0	×	32	9

The cost of the establishment, exclusive of earthwork in the canals, was

	£.
For the buildings, about	15,100
„ machinery „	14,200
Total	29,300

Pumping-Station at Gouda.—The external water-levels (of the Yssel) are—

	Feet.
Mean high water	3·64 + A P.
„ low „	0·55 – A P.
Maximum high water	10·06 + A P.
Minimum low „	4·26 – A P.

When the station was established, in 1857, six paddle-wheels were erected, which in 1872 were changed to wheel-pumps, of which the axis was at 7·21 feet + A P, the lowest part of the drum at 2·50 – A P, that of the buckets 5·78 feet – A P. The total available width of breast was 31·17 feet. In 1873 two of the buckets, of which there were only six, broke, and in repairing them the number was increased to twelve. Under the direction of Professor Henket the buckets were made of a curved form, with the concavity towards the inner water. Since then repairs have been effected by Mr. Rijk, who introduced curves with the concavity towards the outer water, the curvature being that of a logarithmic spiral. At one time three varieties of buckets were in use at the same time on these wheels—three having Mr. Rijk's form, one that of Professor Henket, two nearly flat. It was evident that the difference in the delivery was slight; Rijk's system was on the whole preferable.

The steam-engine here is of the same class as that at Halfweg. The cylinder is 3·65 feet × 8 feet. There are three Cornish boilers, each having 883 square feet of heating-surface. A Table is given showing the performance of the engines during the year 1877, from which it appears that, omitting the months of January, April, and May, when very little work was done, and the lift was small, the consumption of coal was 8·6 lbs. per HP. per hour. Under the same circumstances the Halfweg engines and wheels would have given much better results. In the calculation, the loss of water by slipping and by the partial filling of the buckets was taken at 15 per cent., which is too little. Some experiments gave 22 per cent. for this loss.

General Association of Delfland.—The total area of Delfland, which ranks next in importance to Rhineland, is over 74,000 acres. Its boezem[1] is relatively very small, about 954 acres. Its con-

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[1] Both as regards the internal waters in the dykes and canals, and the external waters in the boezems, the conditions are usually expressed by the ratio between the water-surface at the normal level and that of the whole polder in the former case, and that of the entire group of polders forming a general association in the latter. Thus the water-surface of the boezem of Delfland is $\frac{1}{77}$. Each of the separate polders has its own ratio to the internal waters. These two ratios are quite distinct, and express relations which for new undertakings are determined by very different standards. In the case of the polders the ratio depends upon the power of the water-raising machinery; in that of the boezems, upon the régime of the discharge into natural receivers, rivers or sea, subject to tidal action. When wind was the only motive power, this sufficed to drain the polders, but not as a rule the boezems. For them, therefore, the ratio depended generally solely upon the régime of the natural receivers, upon the duration and extent of the ebb tide, and upon the maximum heights which could be given to the banks of the canals belonging to the boezems. For the polders, therefore, the works had to be so arranged that with the ordinary winds, taking into account periods of calm, the land could be kept as far as possible from submersion. The windmills had to stop working when the wind failed, and also whenever the water-level in the boezem attained a dangerously high level. With the introduction of steam all these relations were naturally changed. In the case of the boezems the regimen of the receivers still remains a most important consideration, as the greater part of the water must be discharged by natural means.

ditions in regard to drainage have always been, and still are, worse than those of Rhineland. Besides the small area of the boezem, the natural discharge into the rivers is attended with difficulty, and there was no artificial means of discharge till 1864, when a station was established at Vijfsluizen, upon the Meuse, not far from Schiedam.

The levels are as follows, referred to the Delfland datum, D. P., which corresponds to 1·071 foot below A P.:—

		Feet.
Internal waters	Minimum	0·82 − D P.
	Maximum	0·66 + D P.
External waters	Mean daily high water . . .	4·00 + D P.
	„ low „ . . .	0·07 + D P.
	Maximum high water, about .	7·02 + D P.
	Minimum low „ „ .	1·74 − D P.

The water is discharged naturally whenever the levels admit. There are six wheels, disposed symmetrically with respect to the motor, of 26·24 feet external, and 12·47 feet internal diameter. The width of breast is 4·92 feet. They work up to 5·38 + DP. The axis is at 8·85 + DP. The radius of the tangential circle is 2·75 feet. The system of construction is similar to that at Halfweg. The engine has a single cylinder 3 ft. 4 in. × 8 ft. 3 in.; the ratio of transmission is 11 : 4·4. The normal velocity of the wheels is 4·4 revolutions per minute. There are three Cornish boilers, 33 ft. × 6 ft. 6 in.; the maximum pressure is 3 atmospheres.

A serious defect in the action of float-wheels is the great diminution in discharging power as the internal water lowers. At Vijfsluizen, for instance, with the inner water-levels at 0·66 − DP, zero, and 0·66 + DP, the volumes of water discharged are respectively 1,092,481, 1,263,133, and 1,421,845 cubic feet; that is to say, that the volume varies from 3 to 4 for the above limits of water-level. The following are the results of two years' working. The year is reckoned from the 1st of May:—

1874–5.—Total number of hours worked, 807. On only thirteen days was water raised continuously during twenty-four hours. The longest stretch of work was 120 hours. The engines were worked so as always to give a useful effect of 104 HP. The consumption of coal was 7·075 lbs. per HP. per hour, including that used for getting up steam and banking the fires while the engines stopped for short periods.

1876–7.—Number of hours in work, 2,086. Continuous work throughout the twenty-four hours on twenty-eight days. Consumption of coal, 6·90 lbs. per HP. per hour.

These results, though deserving of record, are not entirely trustworthy, as they are founded upon the hypothesis that the useful effect is constant.

Mastenbroek Polder.—This pumping-station is interesting from the fact that in 1878 three wheel-pumps were erected there, which had been very carefully studied by two engineers of very high standing, Professor Henket and Mr. Backer. These engineers studied the subject with reference to both float-wheels and wheel-pumps, and left the choice to the constructors, the work being let by tender.

These wrought-iron wheel-pumps were of very different form from that proposed by the original inventor. The specification stated that the diameter of the drum was to be 16·40 feet, two were to be 3·61 feet breast, the third 7·87 feet; the external diameter was to be 23·61 feet. There were to be twenty buckets of the form adopted by Rijk at Gouda, with concavity towards the outer water. The lowest point of the drum was to be at the highest internal water-level. The axis was to be at 5·90 + A P, and the extreme internal and external water-levels 1·47 − A P and 5·92 + A P respectively. The idea of the engineers was to take advantage of the experience obtained at Gouda, and to produce a perfected float-wheel. The play between the buckets and the walls was reduced to a minimum by fastening strips of wood to the edges of the former. The useful effect was prescribed as under:—

Lift.	Expansion of Steam.	Number of Revolutions per Minute.	Discharge.	Useful Effect.	Number of Wheels in Action.
Feet.			Cubic feet.	HP.	
2·80	$\frac{6}{7}$	5·15	15,892	85	3
6·56	$\frac{4}{5}$	4·19	6,745	85	1 (the large one)

It was specified that upon the completion of the work there were to be two trials—one carried out by the drivers and stokers of the constructors, the other by those of the association under the direction of the former. The positions of the water-gauges (a frequent cause of dispute) were definitely fixed, that for the internal water at 39·4 feet from the axis of the wheels, the other at 26·25 feet. The second trial was to last for thirty days during the three months in which the constructor was to be responsible for maintenance. In the event of the consumption of coal exceeding that guaranteed by the contract, the contractor was to pay three-fourths of the capital sum which would have to be paid by the association to provide the additional coal.

There were nine tenders for the work, as under, the names being suppressed.

Number of Tender.	Price for Wheel-Pumps.	Price for Float-Wheels.	Maximum Consumption of Coal in lbs. per HP. per Hour guaranteed.			
			Wheel-Pumps.		Float-Wheels.	
			Lift, 4·26 feet.	Lift, 6·56 feet.	Lift, 4·26 feet.	Lift, 6·56 feet.
	£.	£.				
1	4,831	4,792	6·06	6·06	6·50	6·50
2	5,290	5,290	4·84	4·84	4·84	4·84
3	5,078	5,078	4·84	4·84	4·84	4·84
4	5,375	5,375	5·50	4·95	5·50	5·50
5	6,037	6,262	6·83	6·83	6·83	6·83
6	6,230	6,490	7·40	6·45	7·40	6·45
7	6,361	6,563	6·61	6·61	6·61	6·61
8	6,138	6,338	6·61	6·61	6·61	6·61
9	8,125	8,500	5·72	5·72	5·72	5·72

The tenders were from first-rate constructors, Dutch, German, and English, and are interesting as showing their judgment upon the two systems proposed by the engineers. The prices included the whole of the machinery, with boilers, &c., complete. The contract was let to No. 1, at the rate of £57 per HP. The cost of the buildings was £7,166.

The power was transmitted through the axles of the wheels. The ventilation of these wheel-pumps was not satisfactory, though the question had been carefully considered.

The principal dimensions of the engines were: Cylinder, 2·3 feet × 4 feet; capacity of the condenser, one-third that of the cylinder; diameter of fly-wheel, 16·40 feet, and its weight 7·38 tons; ratio of transmission, 7·81 to 1. The three boilers were of the Cornish type, 28 ft. 9 in. × 4 ft.

When the Author visited the works they had been so short a time in operation that the consumption of coal could not be accurately ascertained, but it appeared that it would be about that of the best engines for water-lifting in Holland, namely, slightly more than 6·6 lbs. per HP. per hour. He considers that the opinion of the engineers is justified, that wheel-pumps and float-wheels are about equally good.

The engine-house is 46·50 feet long, and 18 feet broad. The boiler-house (for three boilers) is 46 feet long, and 27·5 feet broad. The chimney is 78·75 feet high above the fire-grate. Its section increases towards the top, the internal diameter being 3·60 feet at the bottom, and 4·60 feet at the top.

Zuidplas.—This deep lake owed its origin to the extraction of peat. It is not known when this extraction commenced, but there are legal regulations upon the subject as far back as the year 1595. At the beginning of the present century, windmills driving float-wheels were erected to keep down the level of the water in the lake, and in 1825 the Government determined to drain it altogether. The normal level of the water was fixed at 18·40 feet − A P. The highest level in the Yssel, into which the water had to be discharged, was 3·38 feet + A P. The total lift was, therefore, 21·78 feet, and it was decided to divide this into two distinct lifts, each of which was again subdivided into two parts.

The first principal lift was from the low lands to a canal, which was carried round the lake at a certain level. From this canal the water was raised to a collecting basin, and thence discharged into the river by sluices. In this way the basin acted also as a regulator to the river, which is subject to great fluctuations of high and low water in times of flood. These regulating works had to be of much larger capacity in those days, when the motive-power was wind, than would now be necessary. The normal water-level in the circumscribing canal was fixed at 13·38 feet above summer level.

The lift was divided into two parts of 6·69 feet each, and the method adopted was that of Archimedean screws, driven by eleven pairs of windmills. From the canal to the river the water was raised in two lifts by means of float-wheels, the lower worked by seven, the upper by five windmills, a part of the discharge into the river being by gravitation at low tide. This arrangement was, however, modified by the introduction of two steam-engines, of 30 HP. (actual) each. These were attached to a couple of screws, which performed the whole lift of (in their case) 22·18 feet at once. The erection of these engines marks an era in the history of drainage. Although the first attempts at using steam-power were made in 1776, near Rotterdam, the only practical application had been at Arkelschendam, and as these consumed 31 lbs. of coal per HP. per hour, it was thought that steam could not be used economically. The Zuidplas engines consumed 22 lbs. per HP. per hour, which in those days was not considered bad, and led to the adoption of steam for the Haarlem reclamation.

The thirty windmills and the two steam-engines emptied the lake in 1840, and kept it dry. They were all in action up to 1871. Each windmill, with its screw, raised the water from

2,352 acres to a height of 3·28 feet. Each windmill, with its float-wheel, raised that from 1,898 acres for the first half of the upper lift to a similar height, and from 2,656 acres for the second half. The annual cost of maintaining these thirty mills was very high, amounting to about £1,800, or about £60 per mill.

In the meantime the cost and working expenses of steam-engines have been much reduced, while improvements in agriculture require a more perfect regulation of the water-levels, and for these reasons steam has been gradually substituted for wind-power. In 1871 ten mills were removed, and in 1873 it was decided to replace the remaining twenty by steam. A Commission of two well-known engineers was appointed, to whom the following questions were proposed:—

I. What is the best machine for raising 7,240,000 cubic feet of water per twenty-four hours, to a height varying between 11·3 feet and 12·3 feet?
II. When the height varies between 4·9 and 13·1 feet?
III. What is the best system of engines and boilers?
IV. What is the estimated expense?

The answer of the Commission to the second question was decisive: "Centrifugal pumps. No other machine applies so well to differences of level in the external and internal water. No other permits the application upon so large a scale of the whole disposable motive force to all lifts comprised within the limits stated."

"The machine adapted for the maximum lift will, with lower lifts, discharge proportionally larger volumes; while the useful effect which is produced by the coal consumed, does not vary to any great extent."

These statements of the Commission went rather too far. The duty is anything but constant,[1] and while it is quite true that centrifugals adapt themselves more readily to differences of lift, and are available for much higher lifts than float-wheels, they have this disadvantage, which the Commission failed to point out, namely, that there exists in each case a minimum velocity, below

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[1] Mr. Backer, one of the commissioners, has since expressed another opinion founded upon his later experience ("Rapport over den Waterstaatstoestand"), that the consumption of good coal per HP. per hour for centrifugal pumps when working at their full power varies with the lift, and is, for lifts of 7·2 feet, 6·6 lbs.; for lifts of 1 foot, 2·4 feet; and from 3·3 feet to 5·3 feet, 9·37 lbs., 8·82 lbs., and 7·71 lbs. respectively, not counting the coal required for getting up steam, which he puts at 4 per cent. in his own case, but which varies with the number of interruptions to the work.

which they will not raise a drop of water, whereas wheels, piston-pumps, screws, &c., if working at all, always discharge water.

In reference to the first question, the Commission could not say that one form of pump was superior to all others for a high, but nearly constant lift, and they therefore recommend that as centrifugal pumps should be adopted for the second, they should also be adopted for the first case, as they consider them as good as any other form for the purpose, and by having the whole of the machinery from the same firm there would be a saving in cost.

The selection of centrifugal pumps was subject to certain conditions. They were to be direct-acting, the disks to be above the internal water-level, and the delivery-pipe was to be carried by a bend below the low-water level of the external water, so that the lift would vary with that level. Each pumping-station was to have two centrifugal pumps (Gwynne's pattern), driven by separate non-compound direct-acting engines, capable of raising 2,542 cubic feet of water each per minute. The diameter of the disk was to be not less than 6 feet, and the velocity one hundred revolutions per minute. The suction- and delivery-pipes were to be at least 3 feet in diameter. The lower station was to have four, the upper three, Lancashire boilers, 25 feet × 6·5 feet, with twenty-four Galloway tubes. The maximum consumption of coal was to be 6·61 lbs. per HP. per hour, with lifts varying from 5 to 13 feet.

The recommendations of the Commission were adopted, and in 1876 the new machines were set to work.

Tables are given of the performances of the machinery, but before discussing them the Author makes some observations upon the float-wheels adopted. For the lift of 11·8 feet, the diameter of wheel is 32·8 feet, which is believed to be the largest in Holland, though similar wheels, of a larger diameter, are used in Italy. Mr. Forster gives a formula for calculating the diameter as follows. Given i, the immersion of the paddles, p the lift, then the diameter $D = 9 \cdot 82 \sqrt{i + p} = 9 \cdot 82 \sqrt{H}$, in which H = the height from the lowest point of the wheel to the highest external level to which the water has to be raised, the measurements being in feet.

The Dutch use smaller diameters, partly on account of the great weight of their wheels, partly from being accustomed to wind-power, for which they are more suitable. At Katwijk, where the wheels of most recent construction have a lift varying from 12·14 feet to 13·17 feet, the diameter is only 31·17 feet, while, according to the Italian custom, the diameter of the lowest lift should be 39·6 feet. At Zuidplas, $i = 3\cdot28$ feet, $p = 11\cdot8$. D should therefore, by the Italian rule, be 38 feet. It is only 32·8 feet. It should be observed, however, that the Katwijk wheels are similar to those used in Italy, but those at Zuidplas have curved floats, on Korevaar's system, and for this reason the diameter is less than it otherwise would be, as also is the immersion. For this type the inventor gives $D = 2\ H$ as the minimum diameter.

The Author has several times seen the Zuidplas wheels at work. When the levels are favourable the wheel enters the water well, meeting it with the edge of the float; but the lower wheel, which has a high lift, does not leave the water as it should, but throws it to an unnecessary height. The upper wheel, however, with a lift of 8·20 feet, acts better. For the lower, the diameter of 32·8 feet is too little for the lift of 11·8 feet, notwithstanding the curvature of the paddles. This curvature, which is concave towards the internal water, has a disadvantage attending it, that when the level of the internal water lowers to such a depth that the convex surface, instead of the edge of the paddle, strikes the water, it drives the water backwards to a certain extent, instead of carrying it forwards.

The Author now refers to the actual results of the working of the various machines at Zuidplas. There is this notable feature about the works, that there are two pairs of pumping-stations, with machines of two different types, while those of one pair are identical in construction, and work under different conditions as to lift. The volume of water discharged may be taken as constant for each pair. The Tables show that neither with paddle-wheels nor with centrifugal pumps is the consumption of coal proportional to the lift, or to the work done. In the case of the wheels, the contract specified that the actual HP. should be 90 each, and the total consumption of coal (Ruhr of the first quality) should not exceed 595 lbs. per hour with any ordinary lift, with a penalty or premium of £1 13*s.* for each 2·2 lbs. over or under 595. It is hardly necessary to observe that the trial proved satisfactory and obtained a premium. In practice, however, the upper wheel especially was far from satisfying these conditions. The lower wheel, though apparently working under much less favourable conditions than the upper, gives a considerably better effect, owing to the fact that with these wheels the effect increases rapidly with the lift. The weight of each wheel, with its axle, is not less than 21 tons. The velocity of periphery is about 6·5 feet per second. The actual discharge of these wheels is 92 per cent. of the theoretical. It amounts to 3960 cubic feet per minute for each wheel, and the lift being 11 feet 9 inches, the actual HP. is 89. The consumption of coal in ordinary working is 7 lbs. per HP. per hour.

It should be observed that while the wheels very frequently worked day and night, the centrifugals worked generally at intervals, and sometimes for very short periods, as, whenever the state of the tide permitted, the water was simply discharged by gravity through sluices, but the boilers were nevertheless kept in steam, and the consumption of coal, reduced to pounds per HP. per hour, is no doubt greater than it would have been had the pumps been working continuously. The Tables given in the Paper show that the duty of the wheels was somewhat better than that of the pumps, but no doubt this is partly accounted for by the above circumstance. In these pumps the power measured by the water raised varies from 40 to 49·7 per cent. of the indicated HP., and the consumption of coal is 7·67 lbs. per actual HP. per hour.

In one respect, however, the wheels are decidedly more economical, namely, the consumption of lubricants. An inspection of the books for 1877 shows that the consumption per HP. per hour was—

	Pint.
For the wheels	0·0053
„ centrifugals	0·0123

The principal dimensions of the buildings are—

For the float-wheels—

	Feet.
Outside length of engine- and boiler-house	69
Outside width of engine-house	37
„ „ boiler-house	40

For the centrifugals—

	Feet.		Feet.
Internal dimensions of room for two pumps	33	by	28
„ „ boiler-house	36	„	42
Coal store (not roofed)	98	„	66
Engine driver's house	33	„	27

The two steam-engines, with the two wheels of 32·8 feet diameter, and another, not working, of 16·4 feet diameter, cost £5,000, or per HP. £28.

The four centrifugals, with engines and boilers, cost £11,833, or per HP. £46.

The cost of the buildings is not given. Mr. Korevaar says that the cost in pounds of float-wheels, including all machinery and buildings complete is 666 + 66 *k*, in which *k* is the horse-power. This rule applies to all powers between 6 and 100.

Bullewijker-polder.—At this polder very careful experiments have been made by the engineer, Mr. Elink Sterk, upon the performances of the centrifugal pumps supplied by Messrs. J. and H. Gwynne, of which the following are the dimensions:—

	Feet.	Inches.
Diameter of steam-cylinder	1	8
Stroke	1	6
Diameter of the disk of the centrifugal pump	5	7
Width of blades at the periphery	0	5¼
Angle of the blades at the periphery	17°	
" " " axis	90°	
Diameter of the suction- and delivery-pipes	2	6
	£.	
Cost of engine, pump and one boiler (heating-surface 743 square feet)	2,154	
Cost of a reserve boiler	472	
Total cost	2,626	

This is exclusive of erection, and of suction- and delivery-pipes.

Observations on the consumption of coal.

Lift from	14·3 feet to 15·3 feet.
Discharge per second, maximum	41·8 cubic feet per second.
" " minimum	32·5 " "
" " mean	36·0 " "
Mean effective HP.	62·219
Consumption of Westphalian coal during the experiments, which lasted 6 1/20 hours	1,938 lbs., or 5·22 lbs. per HP. per hour.
Number of revolutions, from	134·4 to 136·5
Pressure in boilers, from	66 to 76 lbs.

Experiments with the indicator.

Pressure in boiler	71 lbs.
Introduction, from	10 to 14 per cent.
Vacuum in condenser	25½ inches.
Revolutions per minute	135·8
Indicated HP.	117·7
Discharge per second, from	40·26 cub. ft. to 40·64 cub. ft.
Lift	14·5 feet.
Effective HP.	68·57 to 69·07
Ratio of effective to indicated HP. from	0·583 to 0·587

In these experiments the water was measured very accurately. The results are the more satisfactory because the suction- and delivery-pipes were unusually long, 49 and 85 feet respectively. These pipes are not of constant diameter, but diminish as they approach the pumps.

It appears that in Italy centrifugal pumps have been discredited, owing to unsatisfactory results obtained from a set erected at Codigoro in 1874 by Messrs. J. and H. Gwynne, and the Author is desirous of pointing out the great improvements effected since that date.

North Sea Canal.—In order to regulate the level of this canal, which receives the waters of very extensive boezems, and of the polders formed upon the bed of the Y, the company have been obliged to erect several pumping-stations, of which the principal is that of Schellingwoude, near Amsterdam. A peculiarity of these pumping-stations is the application of Appold's turbine pumps, which the Author describes.

The results were by no means satisfactory, the consumption of coal being not less than 11 lbs., but it is to be noted that the actual quantity of water raised was in excess of that for which the engines were designed, and it was upon this latter that the calculations were made; also that the lift was less than was expected, which would partly account for the excessive consumption. These turbines, in consequence of these results, are now never used.

Turbine pumps on a very small scale are used for draining small areas of about 75 acres, with lifts of less than 1 foot 6 inches. They are made of wood, and driven by wind power. They occupy a space of 4 feet by 4 feet, and cost between £16 and £25.

Except in this diminutive scale turbine pumps are not now in request in Holland. In Italy on the other hand they are said to answer well.

City of Rotterdam.—Rotterdam has three pumping-stations with machinery of an entirely different character to any of those previously described. Their use is to regulate the water-level in the suburban part of the town called Polderstad. They discharge water into the Meuse, and also introduce fresh water from the river into the canals. The canals are greatly polluted by sewage matter.

There are three pumping-stations, two of which are provided with lift and force pumps, the third with a Fijnje's pump,[1] which is driven by an engine with a cylinder 2·75 feet × 6·89, the size of the pump being 6 feet × 4·92 feet. The cost of the whole machinery was £4,166, or £104 per HP.

A Table is given, showing the performance and duty of this and the other two pumps at Rotterdam.

Fijnje's pumps are very simple, but have the disadvantage of requiring deep foundations.

Haarlem Lake.—A description of Dutch pumping machinery would be incomplete if no mention were made of the three pumping-stations which have dried up and keep drained the former lake of

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[1] These pumps were first used in Holland in 1847. They have since been introduced into Germany, and lately into America, where, owing to their success at the Philadelphia Exhibition, they have been applied on a large scale at several places.

Haarlem, covering an area of 44,480 acres. The emptying of the lake was begun in 1849 and finished in 1852. A Table prepared by the engineers, Mr. Van de Poll and Mr. Elink Sterk, is given, showing the performance of the engines at the three stations, Cruqius, Lijnden, and Leeghwater. The dimensions of these machines are:—At Leeghwater, engine cylinders, small, 7 feet, large, 12 feet diameter, stroke 9·3 feet; pumps, 11 in number, diameter, 5·25 feet, stroke, 9·3 feet. At Cruqius and Lijnden, the diameters of the cylinders as above, stroke, 8·86 feet; pumps, 11 in number, diameter 6 feet, stroke 8·86 feet. Ratio of the effective to the calculated discharge (at the normal velocity), for Leeghwater about 84 per cent. (this is somewhat doubtful), for Cruqius 89 per cent. (this figure is reliable). The consumption of coal as found by records extending over a considerable time is 6·83 lbs. per HP. per hour.

Mr. Sterk made some experiments with a view to ascertain the difference in working at the normal speed of about 7 strokes per minute, and when this was reduced to 3 strokes. With seven pumps at work, he found that in the latter case the indicated HP. was 192, the effective 134 HP., or 0·698 of that indicated. The consumption of coal was 5·44 lbs. per indicated, and 7·80 lbs. per effective, HP. per hour. When working 7 strokes per minute, the indicated HP. was 492, the effective 361, the consumption of coal 4·94 lbs. per indicated, and 6·74 lbs. per effective, HP. per hour.

The coefficient of useful effect of the pumps is higher than that of any other machines in Holland; that of the motors on the other hand is small, and the consumption of coal per indicated HP. per hour is more than double that of good modern engines.

Comparative notes upon the various systems.—Besides those described, various other hydraulic machines are in use in Holland, notably a species of Archimedean screw, which is very simple in construction and easily erected. It is well adapted for working by wind-power, and is a most useful machine for lifts which are too high for wheels. It requires, however, that the level of the external water should be nearly constant.

From analytical investigation, and from experiments carried out under certain conditions, it would appear that the best hydraulic machines are piston-pumps, and the worst centrifugals. Notwithstanding this fact, however, it is certain that in Holland, where pumping-machinery is used to such a very large extent, centrifugal pumps are preferred, and piston-pumps are the least used. In all pumping-machinery the duty varies greatly with the lift; this is recognised by the makers of centrifugals, so that in recent con- t least three conditions of lift are specified, and for each the consumption of coal per HP. per hour is fixed. In the opinion of one of the principal Dutch authorities, the mechanical effect differs much less than is imagined between different classes of machines, and in designing a new establishment the greatest importance should be attached to other circumstances; such as the turbidity of the water, the probability of the internal water-level being permanently lowered in time, the nature of the foundations, the method of establishing communication between the inner and outer water, the level at which the machine can be placed with reference to the water to be discharged, upon which depends to a greater or less extent the facility of superintending and repairing the machinery, the security against inundations, the frequency of frost, &c.; also the cost of erection and working.

When flood-water conveying a large amount of *débris* has to be raised, piston pumps are unsuitable, as they are liable to be damaged, and to have their valves choked. Centrifugals are better in such cases, but wheels are the best, and they have the further advantage that they can be easily repaired by ordinary workmen. The motors may be of common types, the only difficulty being that of adapting them to low velocities. With a diameter of 30 feet for instance the wheel must not make more than four and a half revolutions per minute, and with a single system of gearing the speed of the engines would have to be limited, for, with an ordinary speed of 70 strokes per minute, the ratio of transmission would be $\frac{1}{15 \cdot 5}$, which is too high. On the other hand the tendency is to construct engines to work at high speeds, as being more economical.

Again, the system of direct action between engine and pump is the one which is most economical in fuel, but here the difficulty is that too high a velocity is required; for instance, at Legmeer, the engine makes 168 strokes per minute.

In regard to foundations, wheels are at a disadvantage compared to centrifugals, for, with a high lift the wheel must have a large diameter, the sill must have a low level, and this necessitates massive and deep masonry. In some cases this question of foundations is a very important one, and would determine the kind of machinery employed.

Another important point is the liability of the internal water to have its level permanently lowered. With machines in which the water is conducted to the pump by pipes, additional lengths can always be added to the piping, and the only difference is that the consumption of steam will be greater, but with wheels, screws, and possibly with force-pumps, a lowering of the level of the water would require costly alterations.

It is well known that such alterations of level occur in draining marsh-lands, and their amount varies with the nature of the soil; their extent is small in the case of sand, larger in clay, and greatest in muddy ground.

In regard to the separation between internal and external waters the easiest and safest arrangement is that of pumps which discharge the water through pipes which are inserted in masonry walls of sufficient thickness. With wheels and screws much larger apertures are required, and these must be protected by strong sluices.

The Dutch hydraulic authorities state as general principles that for lifts above 16 feet 6 inches, wheels cannot be used, as their diameter would be too great. When the level of the external water is subject to great fluctuations screws cannot be used, as the amount of fluctuation allowable depends upon the radius of the screw, which cannot be more than 4 feet. When the water is very turbid, valve pumps are inadmissible; for moderate lifts, particularly when pretty constant, they recommend float-wheels, if for no other reason, on account of their simplicity and well-known durability.

It may be stated in general, that the useful effect of every machine varies greatly with the lift, and that in estimating the consumption of fuel, it is not enough to take the mean ordinary lift, but the variations must be studied and grouped together, the consumption due to each lift per HP. per hour must be computed from the results of existing machines.

The following Table shows the number of pumping machines of different types erected in Holland in the years 1875 to 1881 :—

——	1875.	1876.	1877.	1878.	1879.	1880.	1881.	Totals.
Float-wheels	3	1	1	4	12	9	8	38
Centrifugal pumps	1	1	6	6	11	9	16	50
Float-wheels and centrifugal pumps, combined	..	..	..	1	..	1	1	3
Wheel-pumps	..	..	..	1	..	1	..	2
Screws	3	1	7	2	12	4	1	30
Piston-pumps	..	..	1	1	..	..	2	4
Various	3	..	2	6	..	1	..	12
Totals for each year	10	3	17	21	35	25	28	139

The Author concludes from the result of his investigations that no general rule can be given as the employment of one or other of the different machines, but that all the circumstances of each case must be considered before a decision is come to as to what machine to use.

TABLE SHOWING the COST of VARIOUS PUMPING-STATIONS ERECTED in HOLLAND DURING the LAST TEN YEARS.

Class of Water-Raising Machines.	Locality.	Particulars of Machinery. d = diameter; l = length; h = lift.	Horse-Power.	Cost of Buildings per HP.	Cost of Machinery per HP.	Cost of Buildings and Machinery per HP.
				£.	£.	£.
Float-wheels.	Waterland. .	2 engines, 2 wheels; $d=25' 6''$, $l=4' 1''$, $h=5' 3''$ . . .	100	56	45	101
	Groot en Klein Vuijlcop . .	1 engine, 1 wheel; $d=15' 9''$, $l=2' 9''$, $h=3' 0''$ . . .	20	37	53	90
	Hamerik Mijzijde . .	1 „ 1 „ $d=18' 4''$, $l=1' 4''$, $h=3' 7''$ . . .	27	48	40	88
	Heeswijk . .	1 „ 1 „ $d=18' 6''$, $l=1' 5''$, $h=3' 11''$ . . .	14½	49	57	106
	Rhineland (Katwijk) .	2 compound engines. (Will work up to 615 HP. Dimensions of wheels given in the Paper)	500	30	28	58
	Hoorn . . .	1 engine, 1 wheel; $d=19' 8''$, $l=1' 8''$	20	52	45	97
	Schouwen . .	2 engines, 4 wheels; $d=24' 7''$, $l=7'$ for 2 wheels, and $3' 7''$ for the other two	120	51	56	107
	Bommelerwaard (boven) . .	2 engines, 2 wheels; $d=27' 3''$, $l=3' 11''$ $h=4' 11''$	80	..	..	79
Centrifugal pumps.	Wijde Wormer	2 engines, 2 pumps; $h=16' 5''$ . .	133	37	32	69
	Westland van S. Overcomars	1 engine, 1 pump; $h=8' 3''$ . .	35½	34	34	68
	Stolwijk bij Gouderack .	1 „ 1 „	113	24	44	68
	Purmer . .	2 engines, 2 pumps; $h=14' 9''$ . .	156	36	33	69
	Beemster No. 1	2 „ 2 „ $h=14' 9''$ . .	150	40	41	81
	„ No. 2	The same	150	..	..	76
	4 Baneen van Duiveland .	2 engines, 2 pumps; h = from $1' 8''$ to $9' 10''$ . .	90	..	..	70
	Bullewijker-polder . .	1 engine, 1 pump	62	..	..	60
	Amstelveensche polder . .	2 engines, 2 pumps; $h=19' 8''$ . .	66	..	..	96
	De vier Ambachten . .	2 „ 2 „	100	..	..	72
Wheel-pumps.	Mastenbroek .	1 engine, 3 wheels. Dimensions given in the Paper	85	83	57	140
	Polders van der Eigen, &c. .	6 wheels	200	39	37	76
Screws.	Heer Hugowaard	2 screws; $d=6' 6''$, $h=11' 8''$ . .	120	37	39	76
	Veenhuizen .	1 engine, 1 screw	13	38	45	83
	Zuiderpolder .	1 „ 1 „ $d=6' 9''$, $h=3' 7''$.	25	..	..	116
	Obdampolder .	1 „ 1 „ $d=5' 6''$	29	..	..	100
Piston-pumps.	Krimpen van de Lek . . .	1 engine, 1 pump	30	..	..	94
	Polder Charlois	2 engines, 2 pumps; $d=3' 9''$, stroke $=2' 8''$, $h=16' 5''$	61	..	..	52
	Polder Abbenbroek . .	1 engine, 2 pumps; $h=14' 9''$ . .	54	..	..	70

[APPENDIX.

APPENDIX.

While the proofs of the last sheets were being revised by the Author, he received a copy of the "Tijdschrift" of the Dutch Institution of Engineers, containing a paper by Mr. Korevaar entitled, "What are the most suitable machines for draining polders?"[1]

Though Mr. Korevaar does not in all cases agree with the Author's conclusions, the latter sees no sufficient reason for changing his opinions.

Mr. Korevaar begins by saying that the only machines which deserve discussion are float-wheels, wheel-pumps, suction-pumps, lift- and force-pumps, and centrifugals. He considers that all are effective when rightly proportioned, and that the first outlay does not differ much between them. The real point to be considered is the expense of working, and he endeavours to ascertain what are the most economical in this respect. But first he gives certain rules as to the discharge and lift suitable to each class of machines.

Float-wheels are capable of discharging 8800 cubic feet per minute, and have the advantage that they can be worked at any lift up to the maximum for which they are designed without any useless raising of the water. They will work up to a lift of 12·3 feet, the ordinary limit being 9·84 feet. For screws he states that if the external water-level descends more than about 1 foot 6 inches below the maximum there will be a wasteful lifting effect. Limits of lift and discharge are 14 feet and 3500 cubic feet per minute. For suction pumps he gives 2120 cubic feet and 16 feet 6 inches; for double-acting lift- and force-pumps in pairs a discharge of 5300 cubic feet per pair, and 40 feet or more lift. He estimates the maximum discharge of centrifugals at 3500 cubic feet, and lift 40 feet.

Mr. Korevaar gives the following as the ratios between useful effect and indicated power in the cylinders:—

Float-wheels	0·67
Lift- and force-pumps	0·70
Centrifugal pumps	0·45

He also describes investigations carried on at fourteen pumping stations from September 1880 to May 1882 into the consumption

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[1] Minutes of Proceedings Inst. C.E., vol. lxxiii., p. 433.

of coal by the different classes of machines, the results of which he gives thus in hectolitres of coal consumed per hectare and per metre of lift:—

	Hectolitre.
Float-wheels	1·06
Lift- and force-pumps	1·06
Similar pumps combined with float-wheels	1·04
Centrifugal pumps	1·77

Whence he concludes that centrifugals consume at least 50 per cent. more coal than the other machines.

The Author does not agree with Mr. Korevaar, whose condemnation of centrifugals he considers to be based upon somewhat unfair treatment, those experimented upon being of old-fashioned types, and working under unfavourable conditions. He also however considers that centrifugals consume more coal than any other class of pumping machine, and that suction-pumps consume less. He insists again however on the necessity of a careful examination of all the features of each particular case previous to deciding what machine to adopt.

(*Paper No. 1987.*)

"The Foundations of the Alexander II. Bridge over the Neva."[1]

(Translated and abstracted by William Anderson, M. Inst. C.E.)

This bridge, built by Colonel Struve, of the corps of Engineers, as contractor, was erected between the years 1875 and 1879, and is the second permanent bridge across the Neva. The left abutment and the piers were constructed in caissons sunk by the compressed-air process. The works presented many features of interest, arising from the bad bottom of the river and the peculiar method adopted in placing and sinking the caissons. The total length of the bridge is 1,334 feet, divided into an opening span of 70 feet and five arches. The superstructure is of wrought iron, and has a total width of roadway of 77 feet, 56 feet of which is occupied by the carriage-way. The water attains a depth of 60 feet; the bottom of the river consists of mud, sand, and gravel, resting on blue plastic clay, which, at a depth of 70 feet, is sufficiently hard to require the use of the pick in working, and weighs about 130 lbs. to the cubic foot. The depth to which the foundations were sunk varied from 74 feet to 81 feet. The base of the abutment, which measures 88 feet by 21 feet, is built on a caisson, the wing-walls being carried on piles. The thick pier, forming the abutment of the swivelling portion, has a base of 118 feet by 51 feet, and the piers have each bases 119 feet long by 29 feet broad. The masonry consists of coursed rubble limestone, laid in Portland cement, with ties in granite, and from a depth of 7 feet below the water-line the work is protected by ashlar facing. The caissons were made of plate iron in the usual manner; the lower portions, about 15 feet deep, forming the pneumatic chambers, remained permanently in the foundations; the upper portions were removed after the sinking of the piers had been completed.

The works commenced by an attempt to sink the caisson of the left abutment in September, 1875. Unfortunately it settled down unequally, and it was not till the end of July, 1877, that the

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[1] The original article appeared in the "Ingener Journal" of the Russian Ministry of Ways and Communications for 1883.

sinking was completed. A Körting hydro-ejector was fitted to pump up the mud; it was found to act very satisfactorily. The water-pressure used was 10 atmospheres, and the stream of issuing water contained 26 per cent. of solid matter, as much as 38 cubic yards being raised per day, while by means of one of the ordinary shafts only about 25 cubic yards per day was got out.

The ground, when removed to within 3 feet 6 inches of the ultimate depth, was tested by means of a hydraulic jack acting on a plate 1 foot square; it was found that 12¼ tons pressed the plate in 0·4 inch; 20¾ tons, 0·8 inch; 24½ tons, 1 inch; and 27¾ tons, 1·4 inch.

The air-pressure in the caissons was 2½ atmospheres, corresponding to 85 feet depth of water. The people worked only three-hour shifts, and yet suffered a good deal from weakness and pains in the legs and arms.

The pressure-pumps delivered 246 cubic feet of air per minute, which, for eighteen men, would give 820 cubic feet of air per man per hour, so that inconvenience experienced arose from the excessive pressure, and not from want of air.

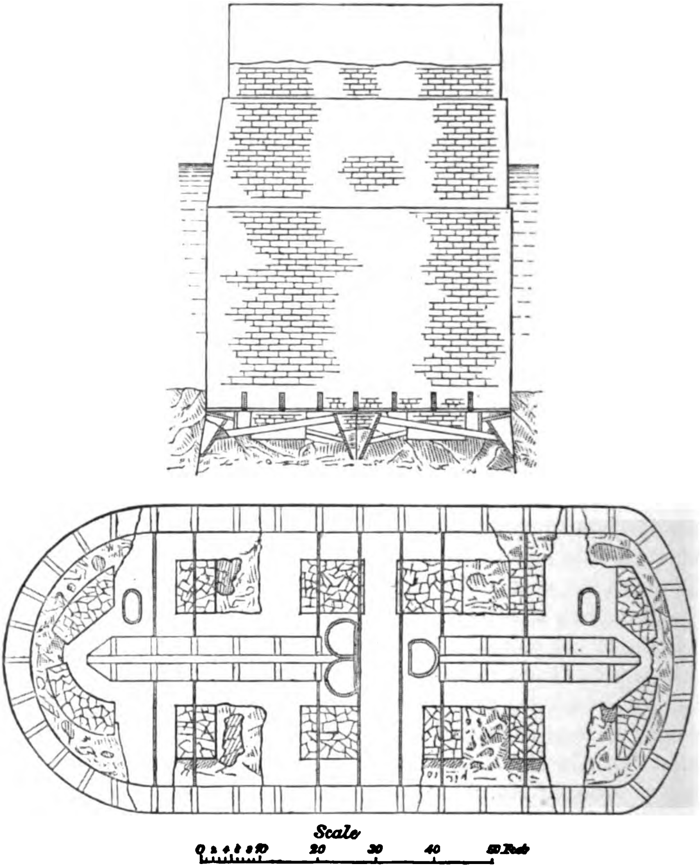
The sinking of the abutment was carried on through the winter. A house was erected over the work, and kept at a temperature of from 54° Fahrenheit to 66° Fahrenheit, during working hours, and was never suffered to fall below 36° Fahrenheit. The temperature of the masonry ranged from 34° Fahrenheit to 43° Fahrenheit; the materials were all brought into the house and suffered to get warm before being used.

The sinking of the abutment of the drawbridge—the thick pier as it is called, also gave considerable trouble on account of the weakness of the caisson.

The sides of the air-chamber were connected to the top by means of gusset-brackets, the spaces between which were filled with masonry in cement before the caisson was submerged. The inner surfaces of the sides were therefore considerably sloped inwards; the consequence was that when the caisson, weighing with its mass of masonry 32,000 tons, sank into the soft ground, a wedge-like action took place which forced out the lower part of the sides, tearing off the gussets from the ceiling of the caisson, and causing great apprehension for the safety of the workpeople. The sides were strengthened by cross-bearers and ties, and masonry pillars were built up inside to prevent any sudden and excessive settlement. At a depth of 71 feet below the water-level the clay was found to weigh 150 lbs. to the cubic foot, and to require a load of 22 tons to sink a plate 1 foot square ¾ inch.

The external pressure was found sufficient to force up the floor of the caisson nearly 6 inches.

The sinking of pier No. 1 was commenced in May, 1876. On the 3rd of August the caisson touched the ground, and the work, under pneumatic pressure, was commenced. On the 16th of September the caisson suddenly sank 18 inches; the comparatively wet mud rose up inside very rapidly; of the twenty-eight men at work in the air-chamber, eighteen managed to escape up the shafts; one unfortunately fell and stopped up the exit, so that nine men remained imprisoned. Of these, two managed to get their heads into the shaft, and were taken out alive after twenty-eight hours' imprisonment; the remaining seven were smothered



between the mud and the ceiling of the caisson. After this accident the works at the pier were stopped for nearly a year, but resumed in September 1877. At first wooden frames were introduced to prevent sudden settlements, and later on, masonry pillars similar to those adopted in the thick pier. Great difficulty was experienced in lighting the workings; stearine candles were found most convenient, but they were easily extinguished by air-currents. In Pier No. 1, four kerosene lamps with artificial ventilation were tried, and appear to have answered well.

The sinking and building up of the caisson were finished in July.

The construction of piers Nos. 2 and 3 presented no features of special interest, and has therefore not been described.

The sinking of No. 4 pier commenced in September, 1876, and was continued through the winter, the masonry being carried up inside a house heated by means of steam-pipes. The ground excavated was very slushy, and the work in consequence went on slowly. In addition, during the month of May, the air-compressing engine became disabled, and excavation was totally stopped for nearly three weeks, during which time the air-chamber and portions of the shafts became filled with mud. On the 9th of September, 1877, the cutting-edge of the caisson had sunk 77 feet below the water-line, and the masonry had been carried up about 3 feet 6 inches above it; the masonry piers in the air-chamber and the timber supporting frames had been prepared for determining the final position of the pier, when, suddenly, one of the air-locks gave way and the air rushed out. Of the workpeople who were in the air-chamber at the time, three managed to escape uninjured; nine were blown out by the rush of air, and, falling on the surrounding craft and into the water, received mortal injuries; while twenty were unable to escape, and were drowned or smothered in the caisson.

The pier sank suddenly about 3 feet 6 inches, thus placing the larger portion of its unfinished upper surface below the water-level, and giving the caisson a slope of 13 inches in the longitudinal direction and an inclination towards the right bank of 1 in 60 transversely. The pier was about 42 feet in the ground, which was 1 foot 9 inches deeper than intended, in consequence of which the cut-water, or rather ice-breaker, required to be pulled down and re-built.

From the circumstance that pumping out of the middle shaft and air-locks caused the water in the two end shafts to sink very slowly, it was surmised that the caisson had received no injury from the accident, and that it would be possible to complete the foundation with the aid of pneumatic pressure. The first step taken was to construct a temporary dam, and attach it to the upper part of the masonry of the pier, in order that the water might be pumped out and the masonry around the shafts raised above the water-line. A house was next built over the work, and provided with heating apparatus.

The next step was to construct completely round the pier a dam of wooden piles and $\frac{3}{16}$ iron plates. It was propped by timber bracing from the pier, and the intervening space filled with clay to a height corresponding to the lower part of the masonry, which had to be relaid. By the middle of February the contractor had succeeded in pumping the water out of the middle shaft to a depth of 63 feet, and, by means of a diver, in opening the door into the caisson. The bodies of two labourers were got out. The structure of the shaft and air-locks was examined, and found to be so much injured that it would be next to impossible to repair them. The lowering of the water in the middle shaft caused it to sink slowly in the two others, so that it became practicable to examine them also. All three shafts had got filled to a depth of some 14 feet with mud and building material of all kinds, and it was evident, from the fact that the water in the end shafts stood 7 feet higher than in the middle shaft, that the caisson was completely full of solid clay. The centre shaft having been so severely injured, and not being indispensable for carrying on the work, was built up with masonry in cement, and the lower part of the space between the iron cylinder and the pier was filled in with cement concrete.

By about the middle of May the air-locks in the lower shaft had been repaired, and air at 40 lbs. pressure was pumped in. The shaft at the upper end of the caisson, which had been temporarily closed, showed no indications of pressure, proving how completely the clay had filled the caisson. The body of one man was recovered and another seen; but the effluvium was so strong, in spite of the disinfectants used, that doubts were entertained as to whether, after all, it would be possible to proceed with the work, and the contractor even proposed to leave the pier as it was, alleging that further subsidence would be impossible. This proposal was taken into consideration and carefully discussed. It was argued that the weight of the pier being about 13,000 tons, and the upward pressure of the air, at the time of the accident, 7,000 tons, that in reality a blow of some 7,000 tons had been given, and the plastic clay, which always showed a tendency to rise up into the air-chamber, had really been driven in with great force, and probably completely filled it right up to the roof. But while the question was still under discussion, about the end of June, the lower shaft had been so far repaired that the caisson was entered, and a gallery 2 feet high driven under the ceiling, both in a longitudinal and in a transverse direction. It was found that the clay had not completely filled the chamber solidly up to the ceiling, but that in places it was as much as 8 inches off it, and consequently the contractor came to the conclusion that it was indispensably necessary to dig out the chamber for a depth of at least 3 feet below the ceiling of the caisson. This was accordingly done, and in a little more than thirteen months after the accident the caisson had been cleared out to the extent above indicated, and filled with masonry. Eleven bodies were found, and the difficulty of working in the vitiated atmosphere, in spite of a liberal use of carbolic acid and permanganate of potash, was great in the extreme. The men worked only one-hour shifts, and constant medical attendance was necessary to counteract the effects of the effluvium. The cut-water was taken to pieces and re-built at the proper level, with the aid of the cofferdam already described; longitudinally the pier is nearly level, but transversely it retains its inclination of 1 in 60 as far as the water-line, above which level it is carried up vertically.

The above account of the difficulties which beset the sinking of the foundations of the Alexander II. bridge, is abridged from the pages of the "Organ of the Ministry of Ways and Communications," in which it is carried on through thirteen numbers, and that record is itself the abridgment of a mass of printed documents forming five volumes of two thousand pages, and consisting of the Minutes of Proceedings of the Committee appointed by the Government to watch over the construction of the bridge, of those of various sub-committees, the reports of the engineers, and other documents. The information contained as to cost of work, the minutest incidents relating to it, the discussions and reports which arose out of each accident, will prove most valuable to any engineers or contractors who may have to design or construct similar works.

There does not appear to have been any officer corresponding to an Engineer-in-Chief; but it is evident that Mr. Sbrojék was the engineer on whom the Committee chiefly relied, and who appears to have justified the confidence placed in him.

OBITUARY NOTICES.

The Rev. THOMAS ROMNEY ROBINSON, D.D., F.R.S., a son of Mr. Robinson, artist, of Windermere, who settled in Ireland under the patronage of the Bishop of Dromore, was born in Dublin on the 23rd of April, 1792. He displayed the most promising poetical talents at a very early age, having written a poem to celebrate Romney, the instructor of his father, when but ten years and eight months old, and a number of other poems which were published in 1806. In January of that year he entered Trinity College, Dublin, of which he was elected a Scholar in 1808, after a strict examination, and a fellow in 1814. For several years he was engaged in lecturing in the University as Deputy-Professor of Natural Philosophy, and in 1820 published a volume entitled "A System of Mechanics for the use of Students in the Dublin University." After a residence for nine years in the University, Dr. Robinson accepted from Trinity College the living of Enniskillen, which in 1824 he exchanged for that of Carrickmacross. On the disestablishment of the Irish Church he took a prominent part in the Representative Church Body. Of his ecclesiastical career there is little further to note, except that in 1872 he was nominated a Prebendary of St. Patrick's Cathedral, Dublin.

Dr. Robinson is principally known to fame by his connection with the Armagh Observatory. This Observatory was founded in 1793 by Primate Richard Robinson, the first Baron Rokeby in the peerage of Ireland, a descendant of William Robinson, who resided at Whitehall, Kendal, in the reign of Henry VIII. Dr. Robinson was appointed Director of the Armagh Observatory in 1824, and threw himself into the work of practical astronomy with great zeal and success. The "Armagh Catalogue," a monument of his assiduity and skill, though not published until 1859, contains many observations of stars between the years 1828 to 1854, of which there are few contemporary observations. In 1862 the Council of the Royal Society awarded to him a Royal Medal for this Catalogue; for his papers on the Construction of Astronomical Instruments, in the Memoirs of the Royal Astronomical Society; and his paper on Electro-magnets, in the Transactions of the

Royal Irish Academy. In divers papers he showed that he profoundly studied the use as well as the mechanical construction of astronomical instruments, the various errors to which they are liable, and the best methods of discovering and eliminating them; and he proved himself to be fertile in ingenious suggestions for the improvement of instruments. The duties of the Observatory, and the preparation of the above-mentioned catalogue, did not prevent Dr. Robinson from devoting a large amount of attention to physical research; as manifested from his papers on the Lifting Power of an Electro-magnet, published in the Transactions of the Royal Irish Academy; on the Stratification of the Electric Discharge; and other papers on analogous subjects. Subsequently, the mural circle at Armagh having been furnished with a new telescope of 7 inches aperture, one thousand stars of Lalande's catalogue, nearly all between 6·0 and 7·5 magnitude, were re-observed in 1868–76, and the results have been published in the "Transactions of the Royal Dublin Society," new series, vol. i. Among his achievements as an astronomer, his determination of the constant of nutation deserves notice. The cup-anemometers, now so extensively used, are an indication of the practical skill and ingenuity by which Dr. Robinson was distinguished. His latest scientific labour was a redetermination of the constants of the cup-anemometer. This was accomplished by experiments on an extensive scale, in the dome of Mr. Grubb's workshops, at Dublin. The results of these labours have been published in the "Philosophical Transactions," 1878–80. Dr. Robinson was a most genial man; in the course of his long life he acquired an immense amount of information on scientific subjects; he was a great reader, and his conversational powers were great; he was elected an Honorary Member of this Institution on the 28th of June, 1842, and died on the 28th of February, 1882.

ROBERT BRUCE BELL was the son of a merchant in Edinburgh. After receiving an excellent education, he proceeded to Glasgow to undergo a practical training to qualify him for his future profession of civil engineering. Acting on the advice of his friends, he determined, in the first instance, to serve an apprenticeship as a mechanical engineer, and with that object in view, he took service with Messrs. Murdoch and Aitken. He afterwards finished his course of mechanical engineering under Mr. Robert Napier, by working as a journeyman at the Lancefield Foundry and Engine Works. Mr. Bell next served a regular pupilage under Mr. Lewis D. B. Gordon and Mr. Lawrence Hill, the former of whom was then the Professor of Civil Engineering and Mechanics in the University of Glasgow—the first occupant of the chair, and he was subsequently a working assistant in his office. It was in the same office that he made the acquaintance of Mr. Daniel Miller, with whom he afterwards entered into partnership and close personal friendship. About 1848 Mr. Bell entered the employment of the late Sir James Matheson, proprietor of the Island of Lewis in the Hebrides, and as Resident-Engineer for that gentleman he carried out a number of important improvements upon the estate, more especially certain sea-walls and dock-works connected with the harbour of Stornoway. In 1850 he returned to Glasgow, and with Mr. Miller settled down in that city to civil engineering practice. The first work of any importance which the firm took in hand was the construction of a slip-dock for Mr. Robert Black on the estate of Kelvinhaugh, now within the harbour of Glasgow, and occupied by Messrs. Aitken and Mansel, shipbuilders. In this slip-dock there was first brought into use the hydraulic-purchase machinery invented and patented by Mr. Miller in the year 1849, and the slip itself was designed for the use of ships up to 800 tons register. Shortly after the completion of the Kelvinhaugh slip-dock, another was constructed on the same principle for vessels of 1,500 tons, and laid down at Williamstown, Melbourne. Subsequently other slips with the same kind of machinery were constructed at a number of ports at home and abroad, including Cronstadt, Alexandria, and Riga. Until about a quarter of a century ago there was not a single graving dock at Glasgow, or one nearer to it than Dumbarton. The first dock of the kind constructed in connection with the harbour of Glasgow was a private one, the owners being the firm of Messrs. Tod and Macgregor, the builders of many of the early iron steamers engaged in the Atlantic mail and passenger service. This dock was designed and carried into execution by Mr. Bell and his partner; and several years afterwards they made a slip-dock for the same firm alongside of the graving-dock, but opening from the Kelvin rather than directly from the Clyde. The same purchase machinery that was then laid down is still in use. About the year 1862 Messrs. Bell and Miller commenced a series of surveys of the harbour of Greenock, in view of certain improvements which it was resolved to carry out under the local Harbour Act. In the first instance they laid out and superintended the construction of what is now the Albert harbour,[1] and as a result of that work being commenced, a difficulty arose as to the mode of disposing of the spoil excavated for the dock enclosure; the so-called "difficulty" had a happy solution, as it eventuated in a great public improvement in the shape of an esplanade along the western shores of the town, a work which was also carried out by the same engineers. At the same time they brought to a successful issue another great improvement at Greenock harbour, namely, the Prince's Pier, in the construction of which there were used piles of greenheart timber, many of which had to be driven to a depth of 100 feet. The Port-Glasgow harbours were also put into the hands of the firm, in order that important improvements might be made upon them, and partly with the view of having the harbourage brought into connection with the Greenock branch of the Caledonian railway system. Then, at the same port, some years afterwards they practically made a new graving-dock on the site of that which had been constructed by James Watt, and which was the first work of the kind in Scotland. They also designed plans for a work of a similar kind at Singapore. One of the largest dry-docks in the kingdom is that known as the Govan Graving Dock No. 1, the designing of which was entrusted to Mr. Bell and his partner by the Clyde Navigation Trustees. Its capacity is such that the "Servia," the "City of Rome," and the "Alaska" have all been docked within its gates; while in the summer of 1883 Sir Edward Reed there inclined, and experimented upon, the ill-fated "Daphne," even though the dock contained two other vessels at the same time, one of them being a very large "Anchor" liner. Shortly after completing the Govan graving-dock, Mr. Bell's firm successfully carried out at Cadiz a spacious graving-dock and a deep-water basin, both suitable for the use of the steamers employed in the mail and passenger service between that port and Cuba, Havana, and the Spanish West Indies generally. In the year 1862 Mr. Bell's firm were engaged by the Harbour Commissioners of Belfast to survey and to report upon plans suitable for an extensive system of harbour accommodation at that port. Several years afterwards they were instructed to report upon feasible improvements that might be made upon the navigation of the River Ribble and on the construction of docks, the Corporation of Preston being desirous of making their town into a great port. In the year 1872 they executed a similar commission for the Cork Harbour Trustees, who aimed at the improvement of

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[1] Minutes of Proceedings Inst. C.E., vol. xxii., p. 417.

the River Lee, and the construction of an extensive system of dock accommodation. They also made a survey of the coast of the River La Plata for an Anglo Argentine Company in 1869, and made a report and designs for a harbour and docks, and a dredged channel for Buenos Ayres. The plans were approved of by the Government of the late President Tarmento, and a concession was promised; but owing to differences between the National and Provincial Governments, these works were postponed. One of the largest dock- or harbour-schemes engaged in by Mr. Bell's firm is that known as the Thames deep-water docks at Dagenham, in designing which they have been associated with Mr. James Abernethy, Past-President Inst. C.E. This scheme involves the utilization of some 400 acres of land, of which 160 acres are intended for an enclosed water area with entrance locks, one of them 700 feet long by 80 feet wide, and the depth of water aimed at is 34 feet. About the year 1875 Mr. Bruce Bell was selected by the Harbour Commissioners of Montreal as one of a Commission of Engineers to report upon a general scheme of improvements for that harbour, his colleagues being Major-General Newton, of the Corps of Engineers of the United States Army, and Mr. Sandford Fleming, C.M.G., M. Inst. C.E., Ottawa, Engineer-in-Chief of the Intercolonial and Canadian Pacific railways. Mr. Bell was elected to serve as the chairman of the Commission.

Mr. Bell chiefly though not entirely devoted himself to dock and harbour work. His firm designed and superintended the construction of the Albert Bridge over the Clyde at Glasgow, which was completed in 1871. Another work of a similar sort was a bridge over the Kelvin, on the road leading from Glasgow to Dumbarton. Messrs. Bell and Miller practically reconstructed the Portland-street Suspension Bridge, Glasgow. They also designed and successfully carried out at least three water-supply schemes, namely, for the town of Grangemouth, and for the cities of Rio Grande and for Pelotas, in Brazil. Mr. Bell was long a leading member of the Institution of Engineers and Shipbuilders in Scotland, serving on the Council as a Vice-President, and as President during the years 1876-78. He was elected a Member of the Institution of Civil Engineers on the 5th of April, 1864. Mr. Bell had settled permanently in London, with a view of directing the business of his London firm; but the weakly condition of his health, which was of several years' standing, rendered him unable to withstand an attack of pleurisy, from which he died at West Croydon on the 13th of August, 1883, aged sixty.

ROBERT REGINALD BURNETT was born in London on the 30th of April, 1841, and was educated in Germany, and at the Athenée Royale in Antwerp. He was one of the Assistant-Engineers on the Riga and Dünaberg Railway, under Sir J. Hawkshaw and Mr. T. C. Watson. On the completion of that line he went to Prussia, and was occupied for nearly two years on the Ordnance Survey of that country. For the next five years he was Chief Resident-Engineer in the department of Cojormala, Peru, where he was engaged in laying out and making roads, constructing waterworks and bridges, opening out and working silver-mines, and surveying the country generally. In 1866 he returned to Europe, and for some time was Resident-Engineer at Berne in the employment of the Swiss Government. He was next appointed Chief Engineer to the Prussian Mining and Ironworks Company, Westphalia, by whom six shafts were sunk from 600 to 1,200 feet in depth; he was also largely employed in the chemical analysis of ores; this appointment he held for ten years. He returned to England in 1876, and was then chiefly engaged in Cornwall in examining and reporting upon various mining works. Towards the end of 1877 he was offered and accepted the post of Engineer-in-Chief to the Chinese Engineering and Mining Company. During his stay of nearly six years in China he prospected, started and brought to a successful issue the coal-mines at Kaiping, near Tientsin; constructed a railway on the 4 feet 8½ inches gauge, about 7 miles in length, and a canal 22 miles long, both in connection with the above-named mines. This railway, which is still in operation, was the first line constructed in China, with authority, and on which locomotives have been permitted to run. The first of the three locomotives now in use was built at Kaiping, was named the "Rocket of China," and made its first trip on George Stephenson's centenary. Mr. Burnett was latterly employed under the same company to inspect and report on the capabilities of coal and iron mines in the valley of the Yang-tse-kiang, and it was during this occupation that he unfortunately caught the typhoid fever, to which he succumbed at Shanghai on the 19th of August, 1883. Mr. Burnett .was elected a Member of the Institution of Civil Engineers on the 6th of February, 1877. Besides being a clever engineer, he was an accomplished linguist, speaking in addition to his native tongue, German, French and Spanish. He possessed great tact in managing large bodies of men, and was much liked and appreciated by all who worked with him and under him.

JOHN OCTAVIUS BUTLER, born in 1812, was the second son of the late Mr. Thomas Butler, of Kirkstall, near Leeds, descended from a family possessing lands at Baildon, near Bradford, for upwards of two hundred years. He was educated at two Yorkshire schools with a view to the engineering profession, and was articled to Messrs. Fenton, Murray and Jackson, engineers, Leeds, in 1829 for five years, and in 1835 went to Messrs. Rothwell and Co., Bolton, as draughtsman.

He entered into partnership in 1848 with his brothers Thomas and Ambrose, and his cousin George Skirrow Beecroft, late M.P. for Leeds, at the old ironworks at Kirkstall Forge, of which the Butler and Beecroft families had been proprietors since 1778. The style of the firm, Beecroft, Butler and Co., was altered in 1858 to the Kirkstall Forge Co., on the retirement of Mr. Beecroft. Mr. J. O. Butler introduced important improvements at Kirkstall Forge, where railway-plant, engine- and bridge-work, steam-hammers, &c., &c., were turned out on an extensive scale, and under his management one of the largest hydraulic forging presses ever made in this country was constructed for forging and stamping of malleable iron on the system of Mr. Haswell, of Vienna.[1]

On his retirement from the Kirkstall Forge Co. in 1878, the engineering department was discontinued, but the extensive ironworks are still carried on by his nephews. Mr. Butler re-edited and greatly enlarged "Beecroft's Companion to the Iron Trade," a work brought out by his uncle, the late Mr. George Beecroft, Sen.

Mr. Butler was for many years Major in the 1st West York Artillery Volunteers, was a Justice of the Peace for Leeds, and held various other important offices in connection with his native town. He died from paralysis on the 16th of October, 1883, after an illness of eighteen months. Mr. Butler's connection with this Institution dated from the 12th of March, 1844, when he was elected an Associate; he was transferred to the class of Members on the 27th of January, 1857.

EDMUND SMALL CATHELS was born near Perth in 1827. Coming to London he acquired considerable practical experience at the Surrey Consumers Gasworks under Mr. George Anderson,

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[1] The Journal of the Iron and Steel Institute, 1876, p. 428.

then Engineer of the works. In 1853 he was employed at Northfleet, and was appointed Manager of the gasworks at Northfleet. In 1856 he became Resident-Engineer of the Gasworks and East Dover Waterworks, Dover, and in 1861 Engineer and Secretary of the Shrewsbury Gasworks, a post which he occupied till 1866, meanwhile designing and carrying out the Curwen Gasworks. At the latter date he was appointed Engineer to the Crystal Palace District Gas Company. In 1872 he left England under a five-years' engagement as Engineer and Manager of the New City Gas-Company at Montreal, where he carried out very extensive works. On fulfilling this engagement he commenced business on his own account as a Consulting Gas-Engineer and Lessee of Gasworks in the United States and Canada. Mr. Cathels occupied these positions with credit to himself and satisfaction to those whom he served. He was the inventor of a district gas-governor, of a four-way disk-valve, and in conjunction with Mr. D. Terrace, of Glasgow, introduced an improved valve. He was author of "The Gas Consumer's Manual," and other works, and was one of the founders of the British Association of Gas Managers (now the Gas Institute) in 1863. A week or two before his death, which took place on the 29th of April, 1883, at St. Paul, Minnesota, from pneumonia, he accepted the position of Engineer and Superintendent of the gasworks of that city. Mr. Cathels was elected an Associate of this Institution on the 7th of May, 1872, and was transferred to the class of Members on the 30th of October, 1877.

ALEXANDER DRYSDALE, son of Robert Drysdale, an engineer and surveyor, was born on the 14th of January, 1817, at Dumfermline, where he was educated at the Commercial School, and afterwards by a private tutor. At the age of seventeen he was articled for three years to Mr. George Buchanan of Edinburgh, it being stipulated that time was to be allowed him "for attending classes or otherwise improving himself"; however, he was so much employed on extensive surveys in the North of Scotland, including the Cromarty and Beauly Firths, that he was unable to pursue his studies as intended. On the termination of his apprenticeship Mr. Drysdale spent two years at the University of Edinburgh, and attending some private classes. The subjects included Botany, Natural Philosophy, and Mathematics, in the last of which he attained considerable proficiency, particularly in the higher departments, comprising the various applications of the Differential

Calculus. It was his custom to continue his studies during the vacation; and upon one occasion the late Mr. Walker, Past-President Inst. C.E., when on a visit to Mr. Drysdale, senior, was shown a drawing by him so well executed that he took it to London, and shortly after sent for the draughtsman, who entered the office of Walker and Burges, where he remained from the end of 1839 to 1844. During this time he was engaged in preparing drawings for the Tame Valley and Wednesbury Canals for the Birmingham Canal navigations, the cofferdam and foundations of the Houses of Parliament, works of the Trinity Corporation, Dover Harbour, &c. Leaving Messrs. Walker and Burges, he went abroad for the purpose of acquiring further professional knowledge, and in 1846 entered the employment of Mr. J. R. McClean, Past-President Inst. C.E., and for the next five years was one of the Resident Engineers on the Birmingham, Wolverhampton, and South Staffordshire Railways, and Stafford and Worcester Canal, under Messrs. McClean and Stileman. Subsequently he was engaged on the Furness Railway, the South Staffordshire Waterworks, the Bristol and Portishead pier and railway, and other important works. In the summer of 1870 the question of the accommodation required in the harbour of Alexandria was referred by the Viceroy, Ismail Pasha, to a mixed Commission. Two plans were considered; one was the proposal of the late Mr. J. R. McClean and Mr. Abernethy; the other that of Linant Bey, Egyptian Minister of Public Works. Mr. Drysdale went to Egypt in June 1870, to represent Mr. McClean, and had several interviews with the Viceroy. As the Viceroy wished to have at Alexandria a harbour as magnificent as any in the Mediterranean, the plan proposed by Linant Bey was adopted, although the area enclosed by the outer breakwater included a large extent of shoal water. The Concession for the construction of the harbour was, however, given to an English firm, Messrs. Greenfield and Co. His mission finished, Mr. Drysdale returned to London, where the organization for the construction of the works was arranged. Mr. Drysdale, spent the winter and spring of the years from 1870 to 1873 in Egypt. While there the use of concrete on a large scale at Alexandria led him to test the value of the materials of the country to form cement. Sufficient Nile mud and limestone from Alexandria were brought to England in the early summer of 1871, and from these an excellent Portland cement was made under Mr. Drysdale's supervision. The cost of fuel in Egypt, however, was prohibitive. In the spring of 1872 Mr. Drysdale visited Trieste, and his observations there influenced materially the mode of construction ultimately adopted for the inner works at Alexandria. In the summer of 1873 the method provided in the contract for the construction of the Mole, as well as its line of direction in the harbour, were brought before the Viceroy, who was then at Constantinople, where Mr. Drysdale went as the Consulting Engineer of Messrs. Greenfield and Co. In consequence of these negotiations the width of the Mole was increased, its mode of construction modified, and its direction altered to an extent which nearly trebled the area of the inner harbour. Mr. Drysdale subsequently went to Alexandria to take the general direction of the execution of the harbour-works, from which Mr. May had retired. These were completed in the summer of 1880. In the winter 1881–2 Mr. Drysdale revisited the works, and had the satisfaction of finding all in good condition. In the autumn of 1882 Mr. Drysdale visited St. John's, Newfoundland, also Halifax and Quebec, having been consulted as to the site and construction of a graving-dock in the harbour of St. John's. He prepared drawings and estimates for a dock to admit the largest ocean steamers, and recommended concrete faced with the native stone as the materials to be used. The St. John's authorities, however, while adopting the site proposed by Mr. Drysdale, decided to build the dock of timber, as being more economical in first cost. This trip appeared to have an injurious effect on the health of Mr. Drysdale, which was never re-established, and he died on the 10th of August, 1883.

Mr. Drysdale was elected an Associate of this Institution on the 7th of March, 1848, and was transferred to the class of Members on the 8th of April, 1856.

ALEXANDER LYMAN HOLLEY[1] was born at Lakeville, in Salisbury, Connecticut, on the 20th of July, 1832. His father, Alexander H. Holley, subsequently Governor of that State, was a native of the same village. He attended various schools in early boyhood, where his healthy physical activity and the overflow of mirth and high spirits made him a leader in sports and adventures. His light-hearted gaiety was the early form of that courage which carried him afterwards through many struggles and even

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[1] This memoir has been abstracted mainly from a memorial address by R. W. Raymond, printed in the Transactions of the American Society of Mechanical Engineers, vol. iv., 1883, p. 35.

defeats, with an air of victory that was the promise of victory to come. To this quality were added a keen observation and an inborn talent for drawing, which were specially directed toward machinery, in which he took the liveliest interest. His father having established a knife manufactory at Lakeville, the boy made himself familiar with all the machinery, and proposed numerous improvements, some of which were adopted. When at the Williams Academy at Stockbridge, Massachusetts, in 1848, he is described as a fair, fresh-cheeked, blue-eyed, wide-awake boy of sixteen. He established a periodical called "The Gun Cotton," issued fortnightly on a large sheet in manuscript, which was read by himself from the desk and afforded great amusement by the variety and spice of its contents. His temperament prompted him to constant activity. There was not a lazy bone or muscle in his body; and beyond doubt, the continuous high-pressure at which he drove his mental energy, during all his life, materially shortened his days. In 1850 a treatise by him on the manufacture of pocket-cutlery was accepted by "Poor's Railway Journal," and published in successive numbers of that paper during the summer. Up to 1849 he had been preparing for the classical course at Yale; but his bent not being in that direction he was entered at Brown University, Providence, in 1850, where he graduated, with the degree of Bachelor of Philosophy in September, 1853. After leaving college, Holley entered the shops of Corliss and Nightingale, at Providence. They were at the time engaged in the attempt to apply to the locomotive engine the principles of the variable cut-off, and he joined the locomotive department, where he served both as draughtsman and machinist; and for some time drove the "Advance" locomotive on the Stonington Railroad. Leaving these works in the spring of 1855 he visited the principal locomotive shops of the West in search of employment, and after much discouragement at length obtained employment in the locomotive works at Jersey City. While working there he married, and there are those who have not forgotten how the young wife trudged daily with her husband to his experiments with coal-burning locomotives on the Harlem Road, or assisted him in the office of the "Railroad Advocate," or haunted the new Bessemer works at Troy, until he was accustomed to say, when fears were expressed for his health, "Don't be afraid; if I die, she can run the concern." When at Corliss' works, Mr. Holley had written both for the "Polytechnic Journal" and in Colburn's "Railroad Advocate" articles on the Corliss engines, which displayed marked ability. From being a contributor to the latter paper he became a partner and editor. After a year Colburn sold out to Holley, who spent much of his time travelling, picking up all that was new to keep up the interest in the paper, and seeking advertisements; but the "Railroad Advocate" languished in the commercial crisis of 1857, and although rejoined by Colburn in July, when Holley's "Railroad Advocate" became Holley and Colburn's "American Engineer," in the following September it was suspended and never revived. But the ingenuity and energy of the owners made this the occasion of a new venture. Securing from a number of American railway presidents and from private friends the necessary means, they went to Europe, to study foreign railway practice, and to report on those features of it which would be most important in America. This was the first of thirteen journeys across the Atlantic made by Holley, every one of which was fruitful of benefit to his country. Colburn and Holley's report appeared in 1851 under the title of "The Permanent way and Coal-burning Locomotive Boilers of European Railways; with a comparison of the working economy of European and American lines, and the principles upon which improvement must proceed." The book was a bold venture, and when it is remembered that Colburn and Holley were in Europe less than three months collecting the materials for it, its completeness and accuracy are a matter of astonishment. During 1858 Holley travelled extensively, soliciting subscriptions from railway companies to cover the cost of publishing the report, and selling other scientific books on commission to cover his expenses. About this period he made the acquaintance of Mr. Raymond of the "New York Times," and his first article in that paper was a vigorous editorial on railway management, published on the 9th of November, 1858. Mr. Holley speedily became a frequent contributor to the "Times" (of New York), and he continued to write at rarer intervals in it till 1875. His most important articles were perhaps those on the "Great Eastern" steamship, written under the signature of "Tubal Cain." In 1859, he accompanied Mr. Raymond to Europe as a "Times" correspondent, made the acquaintances of Brunel and Scott Russell, and thoroughly studied the structure and details of the great ship. In 1860 he again went to Europe for the "Times" and returned on the first transatlantic trip of the "Great Eastern." This time his letters were divided between the "Times" and the "American Railway Review," of which in the meantime he had become editor of the mechanical department, a connection which lasted about eighteen months. His "American and European Railway Practice" was published at the close of 1860. In this work the whole problem was traced with the precision of a judge combined with the earnestness of an advocate. The book was an epoch-making one, and American railway practice in the branches of which it treats has done little more than follow its guidance. In April, 1859, he took out two patents, one for a variable cut-off gear for steam-engines, and the other for railway-chairs. The railway-chair was tried on one or two roads, but it did not come into wide use, probably because reforms in rail-sections and permanent way made the simple fish-plate adequate to all demands. In the spring of 1861 he was a candidate for the position of U. S. supervising inspector of passenger-steamers, in which he was supported by a host of firms and individuals, including the presidents and engineers of the principal American railways, and the managers of great shops for the construction of steam-machinery. In 1862 he was sent to England by Mr. E. A. Stevens, the builder of the Stevens battery, and also the President of the Camden and Amboy Railroad Company, by whom Mr. Holley had been employed, to investigate the subject of ironclad vessels and ordnance. He found the facts he needed scattered in official documents, monographs, unpublished records, etc., and his note-book became, at the close of 1864, a treatise on ordnance and armour. On one occasion during this visit, Holley desired to study the lines of a new ironclad in process of construction. One of the contractors, whom he had made a friend, said to him, "If you can manage to get into the yard, I will show you all you want to see. But I am powerless to procure admission for you, and I am sure it will be refused if you ask it." Whereupon he hired a stylish carriage, arranged himself in solitary state with folded arms on the back-seat, gave the necessary instructions to the coachman, and drove straight through the big gate into the yard, acknowledging with a bow the presented arms of the guard, as proudly as any Lord of the Admiralty. Once inside, he found his friend, and satisfied his curiosity. In the summer of 1863 he again went to England to get information for Corning, Winslow, & Co., respecting the Bessemer process, on the understanding that if successful they would establish a business in America and take him into partnership. His mission was successful. The Bessemer patents were purchased, and subsequently combined with the conflicting American patents of Kelly. The works at Troy were built and started in 1865, and enlarged in 1867. From this time on, the career of Holley was substantially the history of the Bessemer steel manufacture in the United States. In 1867 he built the works at Harrisburg. About a year later he was recalled to Troy, to rebuild the works there which had been destroyed by fire. Still later, he planned the works at North Chicago and Joliet, the Edgar Thompson works at Pittsburg, and the Vulcan at St. Louis, besides acting as consulting engineer in the designing of the Cambria, Bethlehem, and Scranton works. Concerning the increasing productiveness of the American Bessemer plant, it has been raised from the capacity, per two converters, of about 900 tons per month to more than 10,000 tons for the same period; and it may be said that Holley's arrangement of buildings and machinery, to secure convenience in handling materials, and his movable converter-bottom and other devices to reduce the time lost in repairs, were mainly the basis of this great advance. To Holley personally the entrance upon these new labours was the greatest change of his life. The chance, for which he had so patiently waited and so thoroughly prepared himself, had come at last. His work changed from the critical to the creative; and a whole side of his genius, repressed hitherto, sprang into joyous power. All his life he had been fond of designing; moreover he recognised the beauty of adaptation, and the great scientific truth that the line of economy is the line of grace. Beneath a strong light roof, or before a well-arranged plant, he found the satisfaction of an artist as well as an engineer. Yet this new activity was not substituted for the older ones; it was rather superadded to them. In January, 1869, he took charge of Von Nostrand's "Eclectic Engineering Magazine," which he edited for a year. In June, 1875, he was appointed a member of the United States Board for Testing Structural Materials; and in 1879 he accepted an appointment to lecture at the School of Mines, Columbia College, on "The Manufacture of Iron and Steel." He wrote these lectures with great care, and took as much pains to assure himself of the proficiency of his class, by vigorous examinations, as if he had been a resident professor. Besides the two early patents, he obtained fourteen others. Ten of these refer to his improvements in the Bessemer process and plant; two of them to roll-trains and their feed-tables; and the remaining two are those of the 8th of July, 1876, and the 1st of March, 1881—the first for a water-cooled furnace roof, and the latter for a steam-boiler furnace, with gaseous fuel. Mr. Holley was President of the American Institute of Mining Engineers in 1875, and Vice-President of the American Society of Civil Engineers in 1876, and one of the founders of the American Society of Mechanical Engineers. He was also a member of the Iron and Steel Institute, and was elected a member of the Institution of Civil Engineers on the 10th of April, 1877, and in the following year contributed a Paper to the Institution on "Chemical and Physical Analyses of Phosphoric Steel."[1] From 1876 onwards a series of Articles entitled "American Iron and Steel Works," from his pen, appeared in "Engineering," which illustrated and described nearly all the Bessemer works in the United States with which he was connected. In 1877 he became Consulting Engineer to the Bessemer Association, the chief object of the Association being to secure certain advantages in common, among others a knowledge of what was going on in similar industries in Europe. This led to an annual visit of several months' duration to England and Europe, during which he acquired the Thomas-Gilchrist basic process for the Association which he represented. He was largely instrumental in the introduction of the open-hearth process for making steel, and one of his last utterances was, in effect, "I should like to live ten or fifteen years longer to aid in realizing the possibilities of the open-hearth process. This would have rounded and completed my professional career; but I am satisfied." It was about 1875 that his strength began to fail. In that year he wrote—"I am going in a week to one of the Elizabeth Islands, off New Bedford, where there is neither mail nor telegraph, to lie on the sea-shore for a week, and try to get strong and sleepy." In the summer of 1880, while on the Continent of Europe, he was taken seriously ill; returning with difficulty to England, he slowly recovered, after many weeks of sickness, from a disorder of the liver. In August, 1881, he was again in England, apparently in better health than he had long enjoyed; but during his visit to the Continent he was overtaken by symptoms similar to those that characterised his illness of the previous year. He returned to England, but did not leave for New York till the 28th of December. The voyage somewhat restored him, but he continued to fail, and expired at his home in Brooklyn on the evening of Sunday, the 29th of January, 1882.

EDWARD JOHN JONES was the son of Mr. George Jones, a medical practitioner of Birmingham, and was born on the 25th of February, 1841. He was educated first at the Birmingham and Edgbaston Proprietary School, now absorbed into King Edward's Free School. After this he entered as student in engineering at Queen's College, Birmingham, attending the usual classes for

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[1] Minutes of Proceedings Inst. C.E., vol. liii., p. 221.

three years, from whence he subsequently took his diploma as Civil Engineer. On leaving Birmingham he became a pupil of Mr. G. W. Hemans, M. Inst. C.E., with whom he was engaged from 1860 to 1865, during which time he acted as Assistant-Engineer on the Warrenpoint Junction, and the Newry and Armagh, Railways, also as Resident-Engineer on the Newry and Grenore Railway, and Engineer to the Rostrevor, and also to the Narrow Water Castle water supplies. On the 3rd of January, 1866, he went out as contractor's engineer for Messrs. Faviel, to construct the Ceylon Railway, where he was in sole charge of the construction, and the erection of the staging and ironwork of the Peradenia Bridge. This contract being finished, he returned to England, and was immediately appointed Assistant-Engineer, 1st grade, in the Public Works Department of India. In December 1868 he was posted to the 1st Division of the Agra Canal, and placed in charge of the Okla subdivision. Here he was engaged in the construction of the headworks and weir, and had charge of 70 miles of the construction of the canal. This weir and dam are 2,438 feet in length, and raise the level of the river Jumna 10 feet above its previous level. He had the satisfaction of completing this work, which, with the canal, was opened on the 5th of March, 1874.

In 1875 he was appointed to the Bhognipur division of the Lower Ganges Canal, and continued to be employed on the irrigation works until his return on furlough to England in 1877.

In January 1879 he recommenced his duties in India on the irrigation branch at Narora, the headworks of the Lower Ganges Canal, and remained there nearly a year and a half; but his health failing, he was transferred to the provincial works at Jhansi, where he was divisional officer until July 1882. He was then obliged to return to England on sick leave, and although his health improved considerably whilst at home, on again going to work in the summer of 1883 it broke down completely. Again he left India on sick leave, but died on the 29th of September, 1883, the day after the sailing of the vessel from Bombay.

He was an active, energetic, and thorough officer, and received the commendations of all with whom he came in contact. At the time of his death he had attained the rank of 2nd grade Executive-Engineer.

Mr. Jones was elected an Associate of the Institution on the 5th of May, 1868, and was transferred to the class of Members on the 19th of February, 1878.

HENRY FREDERICK WHYTE was the fourth son of Captain Whyte, R.N., and was born at Cabinteely, near Dublin, on the 20th of July, 1832. He was educated at Stonyhurst College, and passed from there to Trinity College, Dublin, where he took the degree of B.A. in 1856. Having also received a diploma as engineer, Mr. Whyte acquired the first practical acquaintance of engineering under Mr. Lefanu. His first work was on the branch line of the Great Southern and Western Railway between Rosgrea and Ballybrophy. From here, in 1857, he went to India as an Assistant-Engineer on the staff of the Bombay, Baroda and Central India Railway. Mr. Whyte was early promoted to the position of Resident-Engineer, and during a term of twenty-four years in India his good services were repeatedly noticed with high approval by the Board, and by the Government of Bombay. Having been during many years one of the Company's Senior Resident-Engineers, he was selected as Secretary to the Company in London in 1882. Mr. Whyte was elected a Member of the Institution of Civil Engineers on the 7th of December, 1869. He was a Fellow of the University of Bombay, a Justice of the Peace for the Presidency, and for some years Major Commandant of the Bombay, Baroda and Central India Railway Volunteers. He died on the 4th of May, 1883. In all relations of life Mr. Whyte was held in the highest respect and esteem, and in India, as at home, his memory will be long held in affectionate remembrance.

ISAAC DODDS was born on the 9th of July, 1801, at the Felling Hall, Hewarth, in the county of Durham. He was the second son of Mr. Thomas Dodds, the Viewer for the Felling Colliery, who was killed with thirty-four others in the explosion at the Hebburn Colliery on the 21st of October, 1805. Though the family was left in comfortable circumstances, the misconduct of a trustee rendered it necessary that young Isaac Dodds should be put to work at an early age, and as his education was incomplete, he went in the evenings for instruction to Mr. Willie Woolhave (plumber, glazier and parish clerk), a very ingenious man, who, finding his pupil apt in mechanical notions, taught him to turn, and generally confided to him all his inventions.

Mr. Dodds always spoke of Mr. Woolhave in the warmest terms. "To Willie Woolhave," he said, "we are indebted for the life-boat, though it was patented by a Mr. Greathead; he was also the inventor of the first safety-lamp I ever saw, which was like a large parrot cage enclosing a glass lamp, the air being supplied by bellows worked by the collier's knees, using the air from the lowest strata. Dr. Clanny brought out a lamp about the same time, but I believe the idea was derived from Mr. Woolhave; on the death of Woolhave, the inhabitants of South Shields raised a subscription for a tombstone, on which was carved the life-boat."

In 1814 young Dodds became a pupil of his uncle, Mr. Ralph Dodds, chief viewer to the Grand Allies Collieries, at Killingworth. Being in the office, he remembered a remarkable incident which occurred. The chief engineer of the colliery having fixed an engine to pump the water during the sinking of the colliery, could not start it to work, nor could he find out the cause, when a man named Christopher Heppel came to see Mr. Ralph Dodds, and said to him, "You have a man named George Stephenson in your employ, who says he knows what is wrong with that engine, and could soon put it right." Mr. Dodds replied, "Send him to me; if he does, I will make a man of him." George Stephenson did know the reason, put the engine to work, and was very shortly afterwards advanced in position; being a shrewd, industrious, and well-conducted man, he became a favourite, Mr. Dodds advancing him from time to time. Shortly afterwards followed the improvement by George Stephenson in the locomotive engine, with Mr. Dodds' ideas on the machine; these were carefully studied every hour that could be devoted to it, and no occasion was lost in considering what could be added, altered, or, if necessary, taken away. Young Dodds, being generally present, had full opportunity of hearing all the discussions, and of seeing the various sketches of the proposed alterations. He said, "The engine was made, and I now venture my humble opinion, that for the purpose for which it was required, viz., a colliery locomotive, to draw coals on a railway, it was at that time the very best that had been brought out; it worked most successfully, and all who saw its performance were satisfied that a great step had been made towards a complete locomotive, requiring only time, experience and perseverance to give it all that the votaries of a 'travelling steam horse' desired; it showed that a 'steam horse' was not only possible, but that it contained a germ of speed and power to overcome all animal power."

This engine was patented by Ralph Dodds and George Stephenson, for improvements in locomotive engines, on the 28th of February, 1815. Young Dodds, after this engine had been at work for some time, became satisfied that the method of coupling the wheels was imperfect; he obtained two spinning wheels, and applied a coupling-rod to enable him to work both with one treadle, to do which necessitated a return crank. Having got it to work satisfactorily, he showed it to his uncle and to Stephenson, who afterwards adopted the coupling-rod which is now universally used in coupled engines. In November 1815 he went down the Killingworth pit with Nicholas Wood and George Stephenson to test the safety-lamp which Stephenson had invented. There were present John and William Moody, Robert Cree, Robert Summerside, George Hales and others, numbering seventeen in all. In the first instance, George Stephenson entered the cupboard in which the gas was collected, when the lamp was blown out of his hand and the top blown off, but he said he had forgotten to fasten it down with some copper wire, having only used string. He took the plyers and copper wire out of his pocket and instantly made it secure; he re-entered the small room, and the trial was a perfect success. Mr. Wood at once went in, and he and George Stephenson took in young Dodds, and with much minute care exhibited and explained to him the whole action. When the engine-works were commenced at Newcastle-on-Tyne, he went there as a pupil under George Stephenson. During his apprenticeship he made a model of tho horizontal cylinders for the locomotive engine, and advocated its adoption in preference to the vertical cylinders then made, his principal objection being that, by the vertical action, the rails were injuriously affected. Mr. Stephenson ignored his reasons, saying he felt assured the horizontal cylinders would never do, as the lower part of the cylinders would wear out. Notwithstanding this, when the "Rocket" was made, the cylinders were placed about midway between the vertical and the horizontal position, and Dodds reminded George Stephenson of his former views, and was pleased that he had even made a compromise. After completing his time at Newcastle, he commenced the engineering works at the Felling shore; whilst there he was applied to by Messrs. Wolsey to try and improve the air-pump for the process of boiling sugar in vacuo; after some experimental trials, he succeeded in making the "double-action air-pump" give satisfactory results in 1830. Whilst in London in 1832 a premium was offered in Newcastle-on-Tyne for a machine to weigh coals in carts or wagons. When he returned, Mr. Stephenson informed him that he had entered him as a competitor; he replied that he knew nothing of weighing-machines, as he had never paid any attention to the subject. Mr. Stephenson said, "Isaac, thou can'st invent anything; thou hast three weeks to think over it and make the model in; try for it." The model was made and was put in about half-an-hour beyond the time allotted, in spite of which it was admitted, and the premium awarded to him was paid. Prior to this he had engaged James Hann as an engineer on the "Industry" paddle steamboat; finding out his fondness for mathematics from seeing him working algebraical questions on his shovel with a piece of chalk, he took him into the office, where he worked out the various rules, afterwards published in "Mechanics for Practical Men," by Isaac Dodds and James Hann.

In 1832 he was induced to accept the position of Engineer to the Horseley Iron Works, Staffordshire, and commenced the manufacture of locomotive engines. The first engine being for mineral railways in Wales, the boiler was carried on two separate four-wheeled bogies, or frames, on which the cylinders were fixed and the wheels coupled.

In 1833 he designed the "Star" for the Liverpool and Manchester Railway. The engine had several improvements which were novel at that time, namely, the frame was a solid plate, the horn-plates being welded on; the boiler was made to expand and contract on that frame, in the manner now generally adopted; the cylinders were placed horizontally, outside, and the motion was given to the valve by a return crank, working the eccentric-rod to an arc or link moving by a reversing lever, the position of the eccentric-rod in the arc, which gave the forward or backward motion, and also varied the stroke of the valves. This engine was the first which had the steam-passages made larger in area, the valve opening barely three-fourths for the admission of steam, but opening the full area for exhausting. "Mr. Dodds claimed that this was the first engine made with a solid or plate frame; the first reversing motion acting directly by a reversing lever, and the first arc or link motion, with fixed centres, used; and also the first boiler free to expand on the frame."

Mr. Dodds took up the question of working heavy inclines by a locomotive engine, as against the rope, with Messrs. Stephenson, Locke, Rastrick, and others, and proposed to make an engine that should do the work at the St. Helen's incline, over the Liverpool and Manchester Railway, more satisfactorily than with the rope then in use. With the aid of Mr. Vignoles, Past-President Inst. C.E., he obtained the order, and constructed the "Monarch," which had horizontal inside cylinders, working rocking-shafts at the smoke-box end of the frame, on the end levers of which were coupled the connecting-rods, acting upon outside crank-pins. This engine was considered a very heavy one at the time, being over 20 tons in working order. Mr. Dodds declined taking the loads up the incline until the rope pulleys were removed, which being done, the engine started, and did the work better than had been anticipated. Whilst at Horseley Mr. Dodds made the first large plate, on which to roll plate-glass; the plate weighed 19 tons when completed. To plane the surface was a difficulty, which he overcame by making a machine, the plate constituting the frame, and the tool being made to traverse over it. This plate took three months to plane. In 1835 he received a medal from the Society of Arts for an "improved parallel-motion," and in 1836 another medal for "the prevention of boiler explosions," by making a disk of copper plate over the fire-box, and inserting a plug of fusible metal. The plug, becoming uncovered by the water before the plates of the fire-box, permitted the fire to act upon and melt it, when the steam would be projected on the fire. This practice is now universally adopted, with slight modifications. He also received a silver medal of the Society of Arts for improvements in casting railway contractors' wagon-wheels, rendering unnecessary the cutting the naves to prevent breakage in contraction. About this time Mr. Dodds was sent for by Messrs. Hooper (Government coopers), who had a strike amongst their men, to try and devise some means to cut their staves by machinery. He undertook to make a machine to do their work, if he was allowed a couple of days to think it over. However, he returned in a few hours with a pencil sketch of the machine, which was the forerunner of curvilinear sawing machinery. The machine, when made, was composed of a series of vertical saws, and on a template being fixed on the side of the movable frame, the saws, when working, were kept in the direct line of cut, and would cut as many pieces to the template form as the number of saws permitted. It was used for staves, gunstocks, &c. After a successful career of four years, Mr. Dodds had the misfortune to lose his right eye by an accident, which necessitated his retirement. Mr. Joseph Bramah was desirous to secure his services, and made him a liberal offer to act as consulting engineer with him, and that he should not be required to look on paper. However, he was induced to go to Rotherham by his brother-in-law, Mr. John Stephenson, who had taken the contract for making the Sheffield and Rotherham and a portion of the North Midland railways. On their completion he became the Locomotive Superintendent, and made the first locomotive engine turntable, to work on a smooth outer ring; he introduced various self-acting switches; he dispensed with the leather-cased buffers filled with horsehair, and made buffers with a series of spiral springs, for engines and carriages. Travelling one day to Derby with Messrs. Robert Stephenson and Barlow, the engineers, after lighting a cigar with a paper spill, which he had twisted in a spiral form, he carelessly retained the spill, springing it backwards and forwards between his thumb and finger, when it sprang away some distance; it immediately struck him that if a piece of paper had that power, a piece of steel so coiled would make a capital buffer. Next day he had two large buffers made, one of flat steel, the other of round steel, with the sides flattened, and had them fixed at Rotherham as a stop for the engines to run against. Finding that they answered the purpose satisfactorily, he had a model made for engine buffers, similar in form to those afterwards patented by Mr. Baillie and others, under the title of "volute springs." Amongst his other inventions may be mentioned the little machine for punching, called the "Bear," the "punching and shearing machine," the "rail-straightening press," and the "Jim Crow" used by platelayers. In 1845 Mr. Dodds went to Glasgow with Messrs. Stephenson, Mackenzie, and Brassey, and was interested in making the Lancaster and Carlisle and Caledonian Railways. In 1846 he designed and erected a rectangular wrought-iron girder bridge at the Beattock, on the Caledonian Railway, to carry a stream over the cutting, about 90 feet across, and a roadway over it. This aqueduct or bridge the Government Inspector declined to pass, and was only eventually settled by Mr. Brassey agreeing to become responsible and building two piers. The tests were satisfactory. When Mr. Robert Stephenson first conceived the idea of constructing the Menai tube, he explained his views to Mr. Dodds, who gave him the results of his experience, and advocated the rectangular form of girder in making the proposed experiments. Several wrought-iron girder bridges were erected on the Caledonian and Scottish Central Railways, from 1846 to 1848. In the latter part of 1850 Mr. Dodds took his eldest son, Mr. T. W. Dodds, into partnership, and re-commenced the Holmes Engine and Railway Works, Rotherham. It must be admitted that by the introduction of steeled rails by Messrs. Dodds, who had great prejudices to overcome, but who persevered and spent freely to prove the economy, increased durability, and superior working of steel as against iron, they were the "pioneers" of the rails which railway companies have now almost entirely adopted. Mr. Dodds and his son carried on the engineering works with considerable success, and obtained a reputation for originality of design and excellence of work in the manufacture of locomotive, portable, and other steam-engines, machinery, and railway plant generally. The first of the type of the portable engines now in use was designed and made at these works, and they supplied, not only home railways, but India, Spain, Portugal, and other foreign countries. The panic of 1866, and other adverse circumstances at that time, however, had a disastrous effect, which resulted in the closing of the works some little time afterwards. Mr. Dodds never entered into business again, but retired to live with his son, Mr. T. W. Dodds, until his late lamented decease.

Mr. Dodds possessed great general kindness of character. He always assisted aspirants for invention, and corrected their errors, so as to prevent their waste of time and money, advising them how to proceed. He was a man of simple tastes, but of large desires to know everything, generous to a fault, and not careful for his own interest.

He was scarcely appreciated during his lifetime, and it is only just now to judge him by what he did during his lifetime. Mr. Dodds was elected an Associate of the Institution on the 30th of April, 1839, and was transferred to Associate Member on the formation of that class. He died on the 1st of November, 1882.

ARNOLD HORNE, the eldest son of the Rev. D. Horne, of Hanley, was born at Heckmondwike, in the county of York, on the 23rd of May, 1855. He received private tuition at home, and then was sent in 1870 to Mill Hill School, Middlesex. He passed the junior and senior Cambridge local examinations with honours, and matriculated at the London University, besides carrying off some of the best prizes in the school. He was gold medallist in 1872, and won the same distinction a second time in the following year. He entered the Royal Indian Civil Engineering College, Cooper's Hill, in 1874, and in 1877 received an appointment as Assistant-Engineer, second grade, in the Public Works Department of the Indian Civil Service. After spending another year in England in some of the large engineering establishments, he proceeded to India to headquarters in Calcutta, and afterwards was employed at several of the stations in Bengal, chiefly on public buildings, bridges, roads, &c. He was promoted from second to first grade Assistant-Engineer on the 13th of May, 1881. He was then residing at Durbhungah, Tirhoot. But the climate of India was telling on a constitution which had never been robust. He had suffered from several attacks of malarial fever, when symptoms of laryngeal phthisis began to show themselves. He was ordered a sea voyage, and went to Australia, by which his health was considerably benefited, but the improvement was temporary. A relapse came on, the symptoms became more alarming than ever, and before the close of 1882 he resolved to ask for two years' sick leave. His application was granted by the Government, and he left India on the 1st of January, 1883, with the intention of going to the south of France. But his departure had been too long delayed. He gradually lost strength, and died on board the "Ravenna" (P. and O. s.s.), on the 26th of January. Mr. Horne was elected an Associate Member of the Institution on the 31st of May, 1881.

ARTHUR HEMERY LE BRETON was the son of Mr. P. H. Le Breton, Barrister-at-Law, and for many years a prominent and active member of the Metropolitan Board of Works. He was born at Wimbledon on the 9th of November, 1849, and was educated at a private school at St. John's Wood, and at University College, London, and afterwards for some months at Brussels. In February 1867 he entered the service of Sir John Hawkshaw, Past-President Inst. C.E., and for about twelve months was engaged chiefly in office routine work. Two years later he was employed on the construction of the South West India Dock. In 1871 he was engaged by Mr. John Wolfe Barry, M. Inst. C.E, as Assistant-Engineer in making preliminary surveys and sections for the projected railway from Buenos Ayres to Rosario, and was occupied on this work for about eighteen months, staying on the River Plate until after the completion of the survey. In April 1874 he was appointed Resident-Engineer in charge of the construction of the Louisburg (Cape Breton) Railway, where he remained till the temporary stoppage of the works in October 1875. After this he went as an assistant on the Government Railways in Natal. On returning from South Africa he was employed for a short time on the Isle of Wight, and the Hull and Barnsley Railways, and finally on the Brazilian Imperial and Central Bahia Railway. Whilst engaged on this work he was seized with a violent attack of congestion of the liver, and died on board the s.s. "Minho" on the 13th of October, 1883. Mr. Le Breton was elected an Associate on the 1st of February, 1876, and was subsequently transferred to the class of Associate Members.

HENRY BLACKBURNE PARRY was born in India on the 17th of October, 1848, and was educated at Thorn Park School, Teignmouth, Devonshire, and subsequently at King's College, London. After an apprenticeship of three years in the office of Messrs. Jenkin and Trathan, Liskeard, Cornwall, Mr. Parry, in 1867, obtained an appointment as Assistant-Engineer in the Public Works Department, India, and was attached to the Bombay Presidency. After a short delay he was posted to the Irrigation Department at Sholapur. Here he remained till 1872 engaged in the construction of canals for irrigating purposes, and tanks and works for the water-supply of the town of Sholapur.

In 1872 Mr. Parry visited England to recruit his health, but on his return to Bombay he found that, during his absence, his name had been removed to the Bengal list, the effect of which was, that from being first for promotion to an Executive Engineership, he did not reach that position for eight years. Mr. Parry was now employed on the construction of the Indus Valley State Railway at Sukkur. Here extensive bridge-works were in progress, the erection of station-buildings, and the raising of an embanked way. The line extends from Karachi to Multan, and passes through a most arid, inhospitable country with a deadly climate. The personal inconveniences and the deprivation of the essentials of life and home comforts, of having to "rough it" in mud-wall and thatch-grass huts, or in canvas tents, have been the experiences of some civil engineers; but when to these is added residence in an enervating climate, the physical energies naturally fail, and the life of many a valuable civil engineer is brought to an untimely end either suddenly or by disease.

Mr. Parry was after a while transferred to the Scindia State Railway, and was engaged on the construction of the bridge over the Chumbul river, and then to provincial works in the North-West Provinces. Through his energy and ability great reforms were carried out in those districts. In 1879–80, when hostilities broke out in Afghanistan and Kandahar, Mr. Parry was deputed, with other civil engineers, to construct a branch railway from the Indus Valley line to the Bolan Pass, for the forwarding of troops and commissariat supplies to Kandahar. It is a matter of engineering history how quickly and expeditiously this line was made.[1] At the close of the war this line was abandoned and the engineering staff broken up and dispersed; the subject of this memoir was next

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[1] Minutes of Proceedings Inst. C.E., vol. lxi., p. 274.

in charge of a party to survey for a line of State Railway in the Transgogra districts below the Nepal terai or low lands, for the opening out of traffic and conveying the same to a point on the East Indian Railway near Patna. The line is now being constructed as a feeder railway by private enterprise, and is styled the North-West and Bengal Railway. On completion of the survey and preparation of plans, Mr. Parry again visited England in 1882 on three months' "privileged leave," and returned in December in robust health, to find himself removed to the Madras Presidency, where he was appointed to the executive charge of a survey of a new State line of railway in the Vizagapatam district. It was in the execution of this work that he, in common with every individual in his camp, European and native alike, was smitten down with malarial fever, of which, after a few days' illness, he died on the 2nd of May, 1883.

The Madras Government passed the following order: "The Government deeply regret to hear of the death of Mr. H. B. Parry, Executive Engineer, from illness directly traceable to exposure undergone in the performance of his duties on the survey of the Vizagapatam-Raipur State Railway. The loss which the survey party has sustained by the death of an officer so earnest and so devoted to his work as was Mr. Parry is much to be deplored."

Mr. Parry was elected an Associate of the Institution on the 6th of February, 1872, and was subsequently transferred to the Associate Member class.

HENRY HARRISON, the youngest son of Mr. Joseph Harrison, merchant of Liverpool, was born on the 29th of June, 1822. After being educated at Chester, he was articled to Mr. Bennison, surveyor, of Liverpool. At the termination of his articles, in 1843, he went to Rouen, and acted as Assistant Engineer on the Rouen and Havre Railway, then being constructed by his brother-in-law, the late Mr. Thomas Brassey, in partnership with Mr. William Mackenzie. On the completion of these works, he was employed as assistant agent on the Rugby district of the Trent Valley Railway. He was afterwards agent on the Macclesfield district of the North Staffordshire Railway, where his great perseverance, industry, and success in overcoming the many difficulties met with in the construction of the railway near that town, so much commended him to Mr. Brassey, that, although so young, he gave him entire charge of the Royston and Hitchin Railway contract, which he successfully completed, with the extension to Shepreth, in 1852. In 1853 he estimated for, and took the entire charge of, the contract for the construction of the Sambre and Meuse Railway in Belgium, which, although a heavy work, with long tunnels, he well carried out, at a very moderate cost. On his return to England, in 1855, he took, at a very low estimate, the contract for the railway from Woodford to Loughton. On the death of Mr. Samuel Hirn, in November 1856, Mr. Harrison took charge of the finishing of the Leicester and Hitchin Railway. He afterwards, in 1858, undertook the construction of the Salisbury and Yeovil Railway. In 1861, in partnership with the late Mr. Thomas Brassey and Mr. Alexander Ogilvie, he took the contract from the Metropolitan Board of Works for the Northern Mid-Level Main Sewer, from Kensal Green to Old Ford. Notwithstanding many difficulties, now well understood, but then novelties, such as passing the sewer, 12 feet by 8 feet 6 inches, close under the Regent's Canal, and keeping the traffic open during the time, again carrying it in a 7-feet iron tube, more than 100 feet long, over the Metropolitan Railway, also making it in deep cuttings along narrow streets, and in 3 miles of tunnel under Oxford and other streets, diverting and forming connections with existing sewers, without injuring the adjoining property, he, with great care and attention, successfully finished this great work in 1866. During this time, and with the same partners, he made the Loughton, Epping, and Ongar Railway, and the Bishop Stortford, Dunmow, and Braintree Railway; also the short line from Chertsey to Virginia Water. From 1866 to 1870 he completed the Waterloo and Westminster end of the present Victoria Thames Embankment. From 1867 to 1873 he constructed the Wolverhampton and Walsall Railway; and from 1866 to 1869 he superintended the making of the East London Railway for Messrs. Brassey, Wythes, and Lucas Brothers. In 1870, after the death of Mr. Thomas Brassey, he became the managing partner in England for the construction of the Callao Dock and reclamation works in Peru, which were successfully completed by Mr. James Hodges in 1875. He died somewhat suddenly, at Southsea, on the 7th of September, 1883.

Mr. Harrison's connection with the Institution of Civil Engineers dated from the 4th of May, 1858, when he was elected an Associate.

MAJOR-GENERAL HENRY YOUNG DARRACOTT SCOTT, C.B., R.E., was the son of Mr. Edward Scott, an extensive quarry-owner, and was born at Plymouth in January 1822. At the age of sixteen he entered the Royal Military College at Woolwich, through which he passed in what, even then, was considered a very short period of time, and obtained the sword of honour. In December 1840 he was appointed second lieutenant, and joined the corps of Royal Engineers at Chatham early in 1841. After a stay there of some fifteen months, he was transferred to Woolwich, and in 1843 he received orders to proceed to Gibraltar, where he held the post of adjutant. In 1848 Mr. Scott was appointed assistant instructor in field works at the Military Academy, Woolwich, and it was then that he first came into notice as a man who delighted in hard work, and considered himself sufficiently recompensed for it by the pleasure it gave him.

In addition to his regular duties at the Academy, he was in the habit at that time of attending the laboratory at King's College, London, where he commenced the study of chemistry, and laid the foundation of that knowledge which, at a later date, resulted in his directing his attention to many important questions, notably to the disposal of sewage in large towns. At Woolwich he started a laboratory, with the object of inducing the young officers of the Royal Engineers to study chemistry, and at the same time he instituted a series of experiments on limes and cements, the practical outcome of which was the discovery of the material now known as Selenitic cement: he also undertook an inquiry into the "representation of ground in plans," which he afterwards perfected at Chatham. In November 1851 he was promoted to second captain, and on the 1st of April, 1855, to first captain, in which year he received the appointment of Instructor in Surveying at Chatham. It was an unfortunate circumstance that neither here, nor in any other position which he subsequently held, did he husband his physical resources, but on the contrary taxed his strength to the uttermost, and impaired a naturally vigorous constitution by overwork. Captain Scott proved himself, at Chatham, an invaluable officer; as an instructor of the younger officers, as a lecturer, and as a promoter of whatever organisation tended to raise the standard of efficiency in the corps, he was foremost. He was at this time chiefly employed in arranging a survey-course. Writing upon this subject, General Collinson, a brother officer, observes:—"In the field-sketching branch of this department he worked out his ideas of showing the features of ground by an ingenious arrangement of horizontal hachures, under certain fixed rules as to thickness and interval, which combined pictorial effect with a certain amount of accuracy of slope. This system, or some modification of it, was, after long discussion, adopted in the Royal Military Academy and at Sandhurst, as well as at Chatham, as the basis for the practice of military sketching. But I don't think Scott ever got any reward for this valuable addition to the military education of the army." Captain Scott took a prominent part in establishing the Transactions of the Corps of Royal Engineers, and contributed to them several Papers, he acting for a short time, it is believed, as the editor. On the 19th of May, 1863, he was promoted brevet-major, and on the 5th of December of the same year he became a regimental lieutenant-colonel.

In December 1864 Colonel Scott was appointed to succeed Captain Fowke as the Director of Works at the South Kensington Museum, a position he was eminently well qualified to fill, and in which he was at once called upon to design and execute public buildings of the highest importance. The plans and models left by Captain Fowke, though they indicated the general character of the proposed museum buildings, were scarcely sufficiently advanced to serve for practical purposes; and among the first duties Colonel Scott had to undertake was the completion of the new Lecture Theatre at the Museum, left unfinished by Captain Fowke, and the designs for the Science School. The latter building was entirely executed under Colonel Scott, and it is admitted to be a very handsome addition to London street architecture. It was a condition of his employment that Colonel Scott should avail himself to the utmost of the services of the students who were being trained in the Art Schools, and owing to the nature of the work, the novel character of the building materials, and the varied methods of decoration adopted here, General Scott was remunerated by a fixed salary, in lieu of the usual architect's commission on the work. During the latter portion of the time he was employed at the Museum, he was called on to prepare designs for the completion of the Museum buildings, at a cost of nearly £500,000, and a careful model of this work, which is now placed in the South Kensington Museum, was submitted to the authorities. Many of the separate portions of these buildings were modelled to a large scale, and working drawings were prepared for the south-east and south-west wings. This design differed entirely from that originally projected by Captain Fowke, as the size and scale of the galleries and museums, as planned by the latter officer, were no longer adapted to the requirements of the South Kensington authorities. To the surprise and grief of General Scott, who had always regarded his position at South Kensington as a permanent one, he received notice to surrender his appointment, and to hand over his drawings and models to the officers of the First Commissioner of Works in January 1882, and he was finally dismissed in the month of March following. This sudden termination of his duties, and the cares and anxiety he underwent in consequence, broke his failing health, and he died on the 22nd of April, 1883.

General Scott was the Secretary of the Annual International Exhibitions held in London in 1871 and following years; he succeeded Sir Edgar Bowring as the Secretary to the Royal Commissioners for the Exhibition of 1851, and for a time filled a similar post for the Royal Horticultural Society. He will probably best be remembered by his designs for the Royal Albert Hall and the Museum Buildings at South Kensington. He also carried out several engineering works of minor importance for the disposal of the sewage of Stoke, Tunstall, and other towns. He was a most indefatigable inventor, having obtained no less than fifty-nine patents for cements, lime, and other kilns, for furnaces, for the treatment of sewage, &c. His improvements in firing pottery and other kilns have been extensively introduced throughout the Staffordshire Potteries, and his inventions have caused great saving in the cost of burning lime and cement. Probably his most important discovery was that of the controlling action of sulphuric acid upon quicklime, which was a fact previously unknown to chemists, and is destined, sooner or later, to revolutionize the method of employing lime for building purposes. His inventions connected with the treatment of sewage, and the numerous careful investigations he undertook with respect to sewage disposal, occupied the whole of his leisure time during the last ten years of his life. He not only studied the best mode of dealing with water-carried sewage, but he also devoted great attention to the question of the profitable utilization of excreta. For the treatment of the former he proposed the calcination of the sludge resulting from the lime-process of precipitation, by which means a cement of fair quality is produced. This system he carried out successfully, both at Ealing and Burnley. In his experiments with excreta collected on the pail-system, he suggested the employment of the phosphate of magnesia; and works for the plan he advocated were erected at Blackburn under the company formed to carry out his inventions. By the latter process a manure of considerable value, termed "ammonic fimus," is produced from pail-sewage.

General Scott was a Civil Companion of the Order of the Bath, a Fellow of the Royal, the Chemical, the Linnæan, and many foreign learned societies. He has written much on the sewage question, and received a Telford premium from the Institution for a Paper on "The Manufacture and Testing of Portland Cement," prepared by him, in conjunction with Mr. G. R. Redgrave, which was read on the 11th of May, 1880; he having been elected an Associate of the Institution on the 3rd of February, 1874.

WILLIAM WATSON was born in Dublin on the 25th of February, 1804, and was the only surviving son of Mr. William Watson, who was descended from a Worcestershire family. He was educated at a school in Dublin and at Trinity College, which he entered in 1821, and where he graduated B.A. in 1825. His own wish was to have taken Holy Orders, but circumstances rendered this undesirable; through the introduction of a mutual friend he became acquainted with Mr. Charles Wye Williams, and obtained from him an appointment in the City of Dublin Steam Packet Company. Mr. Watson soon displayed a capacity for organisation, and in a comparatively short time the principal management of the company's inland department was intrusted to him. The navigation of the River Shannon and the Grand Canal formed then an important part of the company's business, and it was considerably developed by Mr. Watson. He commenced the system of working by night as well as by day, and, amongst other improvements, devised a canal passenger-barge, to enable a fast service to be carried on. The means for attaining that object was a vessel of very light draught, which could be towed in advance of its wave of displacement, and so overcome the difficulty previously experienced in attaining speed with the passenger boats. Mr. Watson's barge was constructed of double the ordinary length, which until then had been limited by the dimensions of the locks. The barge had a double bulkhead amidships, and was arranged to part there, so that each half could pass independently through the lock-chambers, and be joined together again. The barge proved entirely successful, and was subsequently bought by the Egyptian Government, and sent out to the Mamodyeh Canal. In 1839 Mr. Watson invented and patented the composite method of shipbuilding; but although this mode of construction has since been extensively used, he derived no pecuniary advantage from it. In

1843 he was elected one of the directors of the company, and was made joint managing director with Mr. Williams; the latter remained the head of the company, but the control and management principally devolved on Mr. Watson. When railway communication was opened between Liverpool and London, the company obtained a contract from the Admiralty for a night mail service between Liverpool and Kingstown, which they ran successfully until the completion of the Chester and Holyhead line. In 1849 the Government advertised for tenders to convey the mails between Holyhead and Kingstown, and Mr. Watson, fearing that the interests of his company would be imperilled if this contract were allowed to fall into other hands, tendered for and secured the contract. When the Merchant Shipping Bill, which subsequently became the Merchant Shipping Act of 1854, was introduced, containing provisions calculated to depress, instead of fostering, the improvement of the Mercantile Marine, Mr. Watson devoted himself to the amending of the Bill; most of its objectionable features were removed, and the measure, to a large extent, placed the law of merchant shipping on a satisfactory basis. To express their sense of his services, the Irish Steamship Association presented him with an address and a valuable service of plate.

The Holyhead mail contract, already referred to, in which economy rather than improvement had been looked for, did not satisfy the requirements of the increased postal and passenger traffic between England and Ireland, and efforts were made in Parliament to secure the establishment of an improved service. Nothing could then have been done unless the City of Dublin Company had consented to surrender their contract; but so far from raising any obstacle, Mr. Watson advised the company to agree to facilitate the proposed improvement to the fullest extent, and became foremost in bringing about the new service. The negotiations, from various causes, extended over several years. According to the original plan, the sea-carriage was to have been jointly performed by the City of Dublin company and the railway company, but many difficulties arose; matters were, however, eventually brought to a conclusion by an offer of Mr. Watson's, on behalf of his company, to undertake the entire sea service. This proposal was accepted by the railway company, the new contract was executed on the 3rd of January, 1859, and the improved service commenced on the 1st of October, 1860.

In a Paper by Mr. Watson presented to the Institution,[1] full

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[1] Minutes of Proceedings Inst. C.E., vol. xxii., p. 574.

particulars are given as to the establishment of this mail service. It was carried on with unexampled success for twenty-three years. No casualty of importance ever took place, and not a single life was lost. The establishment of this improved mail service may be looked on as the principal achievement of Mr. Watson's life. When the management of the Port of Dublin failed to give satisfaction to the shipping interest, Mr. Watson took a leading part in bringing about a reform, and made arrangements for introducing a Bill in Parliament for the purpose. Ultimately, however "The Ballast Board," as the port authority was then called, settled to introduce a Bill, which became law in 1867. From that time until his death Mr. Watson was a leading member of the Port and Docks Board, as the new Corporation was called, and took an unflagging interest in the improvements of the Port of Dublin. One work in particular was mainly brought about by his influence. Old Carlisle Bridge had become wholly inadequate to the requirements of the traffic, and formed besides a mean continuation of a street admittedly one of the finest in Europe. Various plans had been proposed for its improvement, and many persons were in favour of a second bridge, to the east of Carlisle Bridge, and opposed any alteration of the latter, lest the former might not be constructed, but Mr. Watson succeeded in uniting all parties; an Act was passed in the year 1876, Carlisle Bridge was enlarged and reconstructed, and not only fulfils all that was expected in a utilitarian point of view, but architecturally makes Sackville Street and its surroundings a site of which any city might be justly proud.

In his later years Mr. Watson had first one, and subsequently a second son associated with him in the management of the City of Dublin Company, notwithstanding which he continued to give the same unremitting attention to its interests as he had always done. His mind continued vigorous as age advanced, and the soundness of his judgment did not diminish; an instance of this occurred not long before his death; the Post Office had given notice to terminate the mail contract, and had advertised for tenders, in answer to which the City of Dublin Company and the London and North-Western Railway Company had separately tendered on the 1st of June, 1882; months passed without any response from the Post Office, and the general opinion was that the railway company would be the successful competitor. Mr. Watson presided, as usual, at the half-yearly meeting of the City of Dublin Company on the 15th of November, 1882, and then stated that he expected the company would obtain the contract. The correctness of his view was shown by the result, although on the 11th of January, 1883, it was announced that the London and North-Western Railway's tender had been accepted by the Post Office; for an opposition was commenced, which, supported as it was by the unanimous voice of the Irish parliamentary representatives, by the Corporation of Dublin, by the Chamber of Commerce, and by many other influential bodies and persons, resulted in the proposed contract being set aside, and in the end the City of Dublin Company obtained the contract, which was confirmed by the House of Commons on the 23rd of August, 1883. Mr. Watson did not, however, live to see his prediction verified. At Easter he was taken ill, and he died on the morning of the 10th of April, a few days before the Government announced to Parliament their decision not to press the contract with the London and North-Western Railway for confirmation.

While Mr. Watson's reputation for intelligence and wisdom was high, his character for uprightness and integrity was equally so; his aim in life seemed to be the advantage of others rather than his own, and as a natural consequence he enjoyed, to a most remarkable degree, the esteem and confidence of all who came in contact with him. His disposition was reserved, but his genuine goodness of heart obtained for him a love and affection which was widespread. His tastes were literary; books, indeed, were almost the only form of recreation he allowed himself. In all engineering and scientific subjects he took the keenest interest; biblical study, however, especially in his later years, claimed the largest share of his attention. He was a good classical scholar, and when the revision of the New Testament appeared, wrote a short treatise upon it, which was privately circulated. He was an example of a man who, beginning life without any special interest or influential friends, formed, by an unwavering course of industry and integrity, a prominent position of extreme usefulness and singular repute; he was a sincere Christian in the truest sense, and died honoured and mourned alike by friends and relations and all who knew him.

Mr. Watson was elected an Associate of the Institution on the 7th of December, 1852. He was also an Associate of the Institution of Naval Architects, and a J.P. of the county of the City of Dublin.

SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

Periodical Movements of the Ground as indicated by Spirit-Levels. By P. PLANTAMOUR.

(Archives des Sciences Physiques et Naturelles, Geneva, 1883, p. 616.)

The ground-movements observed during a fifth year[1] (1st October 1882, to 30th September 1883), offer a striking analogy to those of the three preceding years, and furnish abundant proof that they are chiefly caused by the temperature.

I. *The Level placed East and West.*—The curve described by the east end still falls steadily. Its greatest depression, viz., 22·45 seconds, occurred twice—at fourteen days' interval—in March, some six and eight weeks respectively after the minimum temperature had been reached; the subsequent cold summer only induced a maximum rise of 19·76 seconds (the smallest rise yet recorded), about seven weeks after the highest temperature had been reached, and on the very day that it attained, so to speak, a second maximum. The continuity, therefore, of a certain mean temperature, rather than its maxima or minima periods, influences the extreme ground oscillations. The gradual fall of the east end is also thus accounted for, as, excepting the severe winter of 1879–80, all the subsequent mild winters have caused this end to fall but moderately, and the cold summers have induced rises even more slight.

II. *The Level placed in the Meridian.*—The amplitude of the oscillation of the south end has been only 6·56 seconds this year and the curve-trace shows that, though this end falls in the winter, it is gradually rising higher and higher each summer. The anomaly presented every year—but never observed as regards the east end—of changes of temperature producing an inverse effect on the south end, is again repeated, and cannot be explained away.

In conclusion, the Author remarks that capillarity and the molecular action of the glass can have but little effect on the bubble-readings, because it is impossible to establish their action in the face of the regularity of the indications under similar circumstances.

E. H. C.

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[1] Minutes of Proceedings Inst. C.E., vols. liv., p. 286; lx., p. 342; lxiv., p. 343; lxviii., p. 321; lxxii., p. 324.

Sources of Error in Spirit-Levelling. By J. B. JOHNSON.

(Journal of the Association of Engineering Societies, vol. ii., 1883, p. 152.)

First premising that the accurate determination of elevations above sea-level is nowadays vitally connected with the development of a nation, the Author proceeds to distinguish between compensating and cumulative errors in levelling, proving that an almost inappreciable error of the latter class may, in 100 miles, amount to more than all the larger compensating errors combined. The sources of error in levelling are next discussed under four heads, viz.:—

I. Errors of observation. II. Instrumental errors. III. Errors from unstable supports. IV. Atmospheric errors.

I. *Errors of observation* are unavoidable, and arise chiefly from the bubble not being carefully centred, or inaccurately read. A table of bubble corrections should be provided whenever the bubble can only be moved by the foot-screws. Errors of $1\frac{1}{10}$ foot are not uncommon with target-rods, but less common with speaking-rods, and are usually sought by duplicating the line; it is, however, more satisfactory to obtain a check on each source of error independently. To avoid errors in reading a target-rod, both rodman and observer should read independently and compare notes. To avoid errors in reading a speaking-rod, two or three horizontal wires are used, a reading taken on each, and the mean used as the proper reading. This method gives excellent results, and is preferred by the Author for this and other reasons which he enumerates.

II. *Instrumental errors* are due—(1) to want of adjustment in the instrument; (2) to the non-verticality of the rod. The former are eliminated by taking equal back and fore sights, especially at turning-points in a long line of levels. The stability of the adjustments is much increased by holding a heavy canvas umbrella over the instrument. The value of the bubble divisions under varying temperatures must also be known when the bubble is read out of the centre, and corrections applied to the rod-readings. Some bubbles change 50 per cent. of their value from a change of temperature in their metallic fastenings. Another small source of error arises from the sluggishness of the bubble; hence a long bubble should be used in preference to a short one.

In the Coast-Survey Precise Levels, instrumental errors of adjustment are removed by reversing bubble and telescope on each back-sight and fore-sight, thus making four pointings for each reading; but this practice the Author condemns, as the perfect stability of the instrument cannot be relied on during the operation.

(2.) The verticality of the rod can be tested by attaching a watch-level to the rod.

III. *Errors from unstable supports* are more important to notice, because they are usually cumulative, and arise mainly from the instrument rather than the rod. They can be only eliminated by duplicating the line in the opposite direction, and taking the mean.

IV. *Atmospheric errors* arise from—(1.) Wind. (2.) Tremulousness. (3.) Variable refraction.

1. Wind shakes both the instrument and the rod; the Author successfully protected the former in a very windy season by wall-tents, 5 × 6 feet, and one 8-foot centre-pole, while he braced the rods by sticks.

2. Tremulousness always occurs in clear sunny weather: it is a compensating error, and can only be remedied by taking short sights. The Author, however, would limit his sights between 100 and 400 feet, even in a perfectly clear and steady state of the atmosphere, if the highest accuracy is sought.

3. Variable refraction proceeds from sudden bursts of sunshine on the line, and is caused either by the nature of the country passed over, or from the sun's motion; if from the latter, it can only be avoided by stopping the work for a time, as this state of affairs is unlikely to last long.

In conclusion, the Author considers that, with proper precautions and a good instrument, 30 miles of line per month can be duplicated with a Y level and a target-rod, and all discrepancies brought within $\frac{5}{100}$ of a foot into the square root of the distance in miles; or the same work with the U.S. precise levels, reading three wires and speaking rods, and all discrepancies brought within $\frac{2}{100}$ of a foot into the square root of the distance in miles. For the last 400 miles of his own work, about nine-tenths of the work has checked within a limit of $\frac{12}{1000}$ of a foot into the square root of the distance in miles, the last 200 miles being done at the rate of 30 miles a month per instrument. The cost, including one complete field reduction and the setting of bench-marks every 3 miles, was about $18 per mile of completed line.

The limit for discrepancies between duplicate lines of levels is—

Under the commission, $d = 5^{\text{mm.}} \sqrt{k}$;

On the coast survey, $d = 5^{\text{mm.}} \sqrt{2\,k}$.

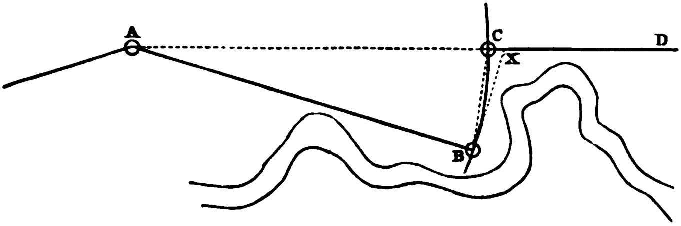
E. H. C.

Transit-Work in Railway-Surveying. By T. APPLETON.

(Journal of the Association of Engineering Societies, vol. ii., 1883, p. 147.)

A light well-made transit, weighing, with tripod and plumb-bob, not more than 23 lbs., is recommended, fitted with shifting head and a level on the telescope with a graduated screw, or else with stadia cross-wires. If the verniers read to single minutes (the index-error being less than one minute), it will do good work. The limbs should read in one direction only from 0° to 360°, the verniers also reading one way only; the telescopic power ld be good, but not too strong, so that a point within 8 feet of the object-glass may be set. A 100-foot steel tape, in one piece, is perhaps best, though a steel wire, brazed-link chain, stands hard usage better. With the ordinary 100-foot chain, it is well in chaining for location to use one $\frac{1}{10}$ of a foot too long, the chainman carrying a small plumb-bob in going up or down hill. The chain should always be dragged ahead its full length when "stepping" on very hilly ground, as else errors of 10 or 20 feet often occur. More inaccurate work is done in the chaining than in the transit work.

In preliminary surveys, an obstacle such as a river or a hill is often met with unexpectedly; the subjoined sketch shows the Author's way of off-setting at it, in order that the new line, extended back, may strike the surveyed line at A, so that the stations may be continuous, and the distance covered without running in the gap A C.



B X is measured at right angles to A B (already run), so that the line through X will clear the obstacle; then having the data for the necessary calculations, the angle A B C is turned, and B C measured, whence C is set, the angle B C A turned, and the survey resumed.

Before tracing a curve, the Author recommends that the readings for every one of its stations should be tabulated, these being arranged so that even degrees or half-degrees occur at full stations; then the odd minutes will only come at plus stations. Tangents should always, when practicable, be run out to intersections, so that every calculation may be made and verified before the curve is run. If the table of readings has been correctly made, the difference between the readings at starting and closing points will equal half the intersection-angle. To throw off a tangent from any station on the curve, set the instrument at the table reading for the station where the transit is. An example, with full instructions, is given, as also a form of note-book for transit work on preliminary surveys.

Curves of small radius (under 400 feet) have been laid out by the Author by making their chords proportional to corresponding curves of larger radius. Thus a 2° curve, with 100 feet chords, has a radius of 2,865 feet; so a 2° curve of 280 feet radius could be run with chords 9·77 feet long, supposing the centre is not accessible.

E. H. C.

The Manufacture of Rosendale Cement in Ulster County, N.Y.

(Engineering News and American Contract Journal, vol. x., 1883, p. 436.)

This paper, which is accompanied by several views of works and of the machinery and kilns in use, describes the manufacture of the celebrated Rosendale cement, so extensively used by American engineers. The cement is named after the town of Rosendale, where it was first discovered and used in the construction of the old Delaware and Hudson Canal. The formation which furnishes the raw material for this cement is an argillaceous magnesian limestone, which extends along the whole of the Appalachian range, and is said to yield three-fourths of the hydraulic cement produced in the United States. There are seventeen distinct layers of limestone, which vary considerably in hydraulicity.

In one of the largest cement works, the method of manufacture is as follows:—The limestone, which is blasted by black powder, is conveyed to the kilns on trucks running along the base of the quarry. It is arranged in layers about 6 inches in thickness with pea-coal between. The kilns are cylindrical, with conical bottom, and are worked continuously, part of the charge being drawn every twelve hours. Imperfectly calcined fragments are returned to the top of the kiln by means of an elevator, the well-burnt pieces being elevated to the top of the mill. Here they first pass through a "cracker," which resembles in construction a large coffee-mill and is made of chilled cast-iron, and can prepare about 250 to 300 barrels of cement a day for the mills. The mill-stones are 3 feet in diameter, and grind the cement so finely that from 93 to 95 per cent. will pass through a sieve of 2500 meshes per square inch. These mills differ in construction from those in use for cement-grinding in England, the upper stone being fixed while the lower one revolves. From the mill-spouts the ground cement is conveyed by "creepers" to the packing-room, where it is packed in paper-lined casks, and is then ready for use. A cubic yard of the cement-stone yields about 2,700 lbs. of finished cement. The barrels are made on the spot by machinery. On account of the varying composition of the different layers of rock, great care is necessary in mixing the stone from different levels in the quarry, and also during subsequent stages of the manufacture. The cement is carefully tested, four briquettes being made every hour; but the moulds used for making the briquettes do not appear to conform to modern European practice. From some experiments made by General Q. A. Gillmore, the crushing-strength of this Rosendale cement is 546 lbs. per square inch in seven days, and 2,015 lbs. per square inch in thirty days. The tensile strength of the neat cement is 104⅓ lbs. per square inch in seven, and 134 lbs. per square inch in thirty days, while that of a mixture of equal parts of cement and sand is 102 lbs. per square inch in thirty days.

W. F. R.

On the Pressure of and Motion in Masses of Dry Sand.
Supplementary paper.

By P. Forchheimer, Dr. Ph., Aachen.

(Zeitschrift des österreichischen Ingenieur- und Architekten-Vereins, vol. xxxv., 1883, p. 103.)

These supplementary investigations[1] were chiefly directed to ascertaining the nature and direction of the slip-surface in masses of sand supported by retaining-walls, when the latter give way, under various conditions, and also when conversely the retaining surface displaces the sand supported by it.

The previous experiments had shown that with a retaining-wall, the inner surface of which is vertical or inclined outwards when the surface of the sand is level, a horizontal displacement or a turning motion about the inner edge of the base is followed by the formation of a slip-surface, having an inclination with the horizon of $\frac{\phi + 90^\circ}{2}$, where ϕ is the natural angle of repose of the material used.

Further experiments proved that when the turning motion of the retaining-wall took place about the outer edge of the base, the slip-surface assumed angles less in the lower and greater in the upper portion than $\frac{\phi + 90^\circ}{2}$. If the surface of the sand has an ascending gradient from the top of the retaining-wall, and the face of the latter is vertical or inclined outwards, two slip-surfaces are formed when a horizontal displacement occurs, the angle formed with the horizon by that having the lesser inclination being greater than the natural angle of repose, and this is the case even when the inclination of the upper surface of the sand coincides with that angle.

According to Winkler, in the case of a mass of unlimited extent in a horizontal direction, if ϕ be the natural angle of repose, ϵ the inclination of the upper surface, and γ that of the lower slip-surface with the horizon, then

$$\cos(2\gamma - \phi - \epsilon) = \frac{\sin \epsilon}{\sin \phi}.$$

The author's experiments showed that this only held good where ϵ did not exceed 20°, but the fact that the mass of sand forming the subject of experiment was not of relatively unlimited extent, may have affected the result at greater angles. When the retaining-wall was displaced in a direction parallel to its surface, the agreement with Winkler's formula was better.

The following is a summary of the cases forming the subject

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 331.

of the author's further investigations, with their results:—Ascending gradient of surface, vertical or outwardly inclined retaining-wall, downward displacement parallel to surface. The slip-surface had a steeper inclination than when the displacement was horizontal. Ascending gradient of surface, inwardly inclined retaining-wall, horizontal displacement. The inclination of the slip-surface when the angle of the retaining-wall with the horizon was small, was less than with a horizontal surface, but when the slope of the wall was considerable the reverse was the case. Descending gradient of surface, horizontal displacement. With a vertical wall the inclination of the slip-surface appeared to be the same as for a horizontal surface $\left(\frac{\phi + 90^\circ}{2}\right)$, but when the wall had an outward inclination, this value was not attained.

The experiments previously made[1] by the Author on the effect produced when sand is displaced by the retaining surface and forced backwards, were extended and completed, the inclination of the displacing force being varied as well as that of the surface of the sand and the retaining-wall. The results showed that the angle of the retaining-wall affected them very slightly, and that the direction of the displacing force was the most important factor.

The latter series of experiments has a geological interest as illustrating the formation of bent strata.

The Author gives all his results in a tabular form. The same method of investigation, as described in a previous paper, was followed, the sand used being arranged in alternate coloured and uncoloured layers.

G. R. B.

The Inspection and Testing of Iron Road-Bridges in Germany.

(Deutsche Bauzeitung, 1883, p. 503.)

According to a decree recently published by the Minister for Public Works, all iron bridges on public roads are annually to be subjected to rigorous inspection and tests.

The parts to which special attention is to be directed in the inspection are—

1. The girder-beds and the brickwork of the piers and abutments.
2. The bed-plates with regard to normal position, freeing them from rust, &c., and eventually seeing that they are in perfect working-order.
3. The riveting at the junctions of bracings, &c., with the booms, especially the existence of loose rivets at points where the greatest strain is borne.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 332.

4. The separate parts of the bridge; whether any fractures have occurred at the rivet holes, and whether bending, rust, or want of paint are manifest.

After the inspection of the bridge it will be evident whether any measurements are required to be taken; if so, they are to be made with a view of ascertaining—

(*a*) The normal height of the bearing-plates.

(*b*) The height of the centre of the bridge, and its camber when unloaded.

(*c*) The amount of oscillation produced by vehicles passing over the bridge.

If, after the above inspection and measurements have been made, the state of the bridge should be doubtful, load-tests are to be resorted to, in order to bring out more prominently any defects which may exist in the structure.

For measuring the deflection a level is generally to be employed, but the use of other means and apparatus in suitable cases is allowed.

J. R. B.

Fall of a Road-bridge at Rykon-Zell, Canton Zurich, Switzerland.

(Schweizerische Bauzeitung, Sept. 22, 1883.)

On the 28th August, a road-bridge, crossing a stream near Rykon-Zell, when being tested previous to its being handed over to the communal authorities by the contractor, suddenly gave way and fell into the stream, causing the death of the Mayor and serious injury to five other persons present.

The bridge (of light wrought-iron open-girders) consisted of 2 spans of a total length of 121·4 feet, there being 2 land spans of 36·25 feet each, and a central span of 68·9 feet; the fatal result ensued from the collapse of this central portion of the bridge, the shorter spans having remained uninjured. The width between the girders was 12 feet.

The main girders of the centre span consisted of top and bottom members of **T** iron, 4 inches wide by 6·3 inches deep, and 0·393 inch thick; the span was divided into 8 bays, and the upper and lower beams were connected by angle-iron verticals 2·75 inches × 2·75 inches × 0·27 inch, ties of flat bar iron 4·724 inches × 0·393 inch, 3·149 inches × 0·275 inch, 2·75 inches × 0·354 inch, in each bay respectively from piers to centre, and two centre struts of **T** iron 3·74 inches × 3·937 inches; the upper members of the girders were curved, the depth on the piers being 4·1 feet, and in the centre 8·2 feet. The roadway was carried by cross-girders of rolled **I** joists, 3·78 inches × 9·25 inches, and longitudinal **I** joists 3·937 inches × 7·874 inches.

The total weight of ironwork in the bridge was 23·16 tons, of which the superstructure comprised 13·28 tons. The bridge was erected by contract at a cost to the Commune of Rykon-Zell of

10,700 francs (£428). It was required according to the specification "to bear a minimum moving load of 60 kilozentnern (5·9 tons)," and to be similar in general construction to the bridges already erected at Rykon and Au.

The operation of testing the bridge was carried out as follows: the proceedings being watched by the Government Divisional and Sectional Engineers, the latter of whom observed the deflections. Three wagons, loaded respectively with 3·92 tons, 3·72 tons, and 3·76 tons, were drawn on to the bridge, one wagon standing entirely on the centre span, and the other two over the piers, so that one half the load of each rested on the land spans. About twelve people were also standing equally distributed on the bridge. In this position the deflection of the central girders was noted at 0·197 inch. The order was then given to draw up the two wagons so that all three might stand at a distance of about 5 feet apart along the centre span. On drawing up the first wagon the deflection increased to 0·295 inch, and on the second wagon being drawn up the bridge collapsed.

The designer of the bridge in his evidence before the court of enquiry states that he protested against the method of loading, but being overruled he went off the central span of the bridge. As the last wagon was drawn on to it, he saw the upper portion of the girder on the south side slightly oscillate, suddenly it bent outwards and fell; a moment later the other girder also bent, and immediately the whole roadway fell in.

From the calculations made by the Author the strain on the main girders, due to the dead-weight and test-load, did not exceed 4·11 tons per square inch, and, while condemning the construction as generally weak and insufficient to bear such a load as might be brought on to it by a crowd of people, he ascribes the disaster primarily to the weakness of the verticals. He says: "When, as in the present instance, the roadway rests on the lower beams, the load on the cross-girders causes a moment of torsion on these beams at the points of connection, which is taken up by the verticals, and in part transferred to the upper members. If the verticals are not strong enough to properly stiffen the girders there will result an inward bending of the compression-beams. As the latter are consequently tilted over, the strain is thrown off the centre, and there will be on one side of their cross-section a tensile strain, while the other side will be excessively compressed, and there will follow a further bending, breaking, and final collapse. In this case the verticals did not suffice to meet the strain of this moment of torsion from the cross-girders, and so bent inwards; the beams followed this movement only in part. The verticals consequently broke just above the stiffening plates, where weakened by rivets. The girder on the south side, in its tendency to regain its position in equilibrium, fell outwards, and the roadway then dropped vertically on to the bed of the stream and was jammed between the piers." The tension-beam on the north side, though slightly twisted, remained unbroken. The two centre struts so far stiffened the centre vertical that it was only slightly bent, and was still in connection with the girder.

The bridges at Rykon and Au, which were to have served as a guide in construction, were more correctly designed, the beams being built up with a horizontal and a vertical plate and two angle-irons, and the verticals with two angle-irons and a plate between. The piers at Rykon-Zell, although in no way contributing to the accident, were designed on the same economical principles as the superstructure. They were slightly tapering cylinders, 15·75 inches diameter at the top, of wrought-iron plates 0·236 inch thick, and filled with concrete. In a position where the iron is likely to be much affected by rust, this small sectional area would, perhaps, continue to bear a direct vertical load, but would scarcely long withstand the vibrations and side strains from heavy loads moving across the bridge.

No remarks are made as to the quality of the iron or the character of the work in the bridge.

The Author, while unwilling to apportion the share of responsibility for the accident, is not satisfied that the designs were sufficiently considered by the public works authorities before granting their approval, nor with the adoption of the competitive contract system by the communal authorities; he strongly condemns the system as leading, for the sake of mistaken economy, to the employment of small unknown contractors, and the exclusion of well-established firms whose names are a guarantee of the work they turn out.

G. E. P.

On River-Embankments. By A. Pestalozza and L. Rossi.

(Il Politecnico, April and May 1883, p. 236, and July, p. 439.)

The embankments[1] of the Po between Cremona and Casalmaggiore were originally placed from 2½ to 3 miles apart, leaving long strips of valuable land between them and the ordinary channel of the river. In many places large tracts of this intervening land have been enclosed by banks, which might be thought to act as outworks to the embankments, and to afford them additional protection. Instead of this, however, they have frequently proved to be sources of danger, as they are more liable to be damaged by floods, and if the river bursts through them the rupture of the embankments frequently follows, the reason being that as these latter always stand dry, except when the banks have failed, they do not get the benefit of the action of the water in filling up small cavities, nor is there any opportunity of discovering defects till a flood comes and it is too late. It is believed

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[1] In this abstract the term "embankment" means the main bank of the river; the term "bank" means a secondary work enclosing land between the main embankment and the ordinary channel of the river.—W. H. T.

that in many instances in which disastrous breaches have been made in the embankments these have been due entirely to the effect of the banks. This danger was illustrated, and happily averted in one instance. The embankment of the Po between the Olona and the Lambro protects an area of 14,000 acres, with a population of nine thousand seven hundred. Between this and the river several tracts of land have been surrounded by banks. In October 1882 one of these banks, enclosing 355 acres, was threatened by a flood, when the engineer in charge ordered two cuts, of about 70 feet each, to be made in it, so as to allow the water to flow through gradually, and to reach the embankment slowly. It was then found that defects existed in this embankment, which began to be undermined by the water; but as there was then time to remedy them, the country was thus saved from an inundation, which would certainly have taken place had the river forced its way uncontrolled through the bank, as it would then have poured with such force against the principal embankment that it would have been impossible to repair it.

Mr. Pestalozza considers that these banks should either be removed altogether, or else made entirely separate from the embankments, or in some cases, when villages have been built under their protection, should be raised and strengthened, so as to act as the principal embankments of the river.

Mr. Rossi, on the other hand, while admitting that these banks are often improperly constructed and become a source of danger, thinks that in most cases they afford real protection, and are, in fact, embankments. He recommends that they should be kept at a lower level than the embankments, the exact height varying in different localities, but being somewhat below the level of ordinary floods, which would then flow over them and give the embankments the benefit of the wash of water which is required to keep them in good order; the damage which the enclosed lands would sustain by occasional flooding would be compensated by the deposit of rich mud left by the water.

W. H. T.

On the Changes in the Mean Surface-Levels of the Rivers Rhine and Meuse. By T. J. Roelants.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1883, p. 205.)

The Author compares the returns of waterheights at different stations of observation on the rivers Rhine and Meuse, taken since 1772 and till 1881, or over a period of 109 years. He calculates from these returns the tendency shown by the mean heights to rise or fall, and finds that, although at Cologne and lower down these mean heights remain practically the same over the whole period, there is a slight rising tendency observable between the years 1866 and 1880.

On the Meuse at Maastricht a falling tendency is observed in the same period between 1866 and 1880, although taking the observations over the whole period of 109 years, there is no change of mean surface.

H. S.

Double Lock of Carrières on the Seine. By — DE PRÉAUDEAU.

(Annales des Ponts et Chaussées, 6th series, vol. vi., p. 245, 3 pl.)

This lock has been constructed, in a side cut alongside the Seine, to replace the Denouval lock, whose sill was only 3⅔ feet below the water-level held up by Meulan weir, and it is consequently one of the first works that has been undertaken for providing a depth of 10½ feet of water between Paris and Rouen. The width of the lock at each end is 39⅓ feet, which is an ample width for any barges navigating the river, and for screw tugs. The lock-chamber has been made 55¾ feet wide to admit two of the largest barges placed side by side, and 463 feet long, so as to accommodate a train of one tug, three large, and three small barges. The smaller lock, placed alongside the other to prevent any interruption of traffic in the event of damage or repairs, has been made 27 feet wide and 197 feet between the gates, so as to hold the largest craft. The lower sill is 10½ feet below the water-level of the lower pool; but the upper sill has been placed 13¾ feet below the upper level, to afford a sufficient depth when the weir is being opened. The filling and emptying of the locks is effected through culverts in the side walls behind each gate. These culverts are opened and closed by sluice-gates turning on a horizontal axis. The sluice-gate is placed in an iron frame which fits in grooves, and can be drawn up for repairs. Four valves in each sluice-gate enable the lock-keeper to regulate the flow at the commencement, and avoid the rush of water which would be occasioned by the sudden opening of the gate. The filling of the lock, with a fall of 10 feet, occupies from twelve to fourteen minutes. This is a notable improvement on the Bougival lock, which, with little more than half the surface, is filled in only one-sixth less time. The foundations were executed out of water by aid of pumping, under the shelter of the natural banks of the cut—a system which cannot generally be adopted on the Seine owing to the great depth of the works. Strong concrete and masonry foundations were placed under the sills and gate-floors, and sheet piling was carried across each extremity of the lock; but the masonry of the invert along the bottom of the chamber was simply made adequate to provide against scour, and not for resisting pressure of water from below, as the clayey soil does not offer a ready passage for water. The lock-gates have been constructed of yellow pine, the several parts being joined by iron straps. Timber was preferred to iron on account of its being cheaper both for construction and repair, as well as lighter. The comparative durability of timber and iron in gates needs further experience. The cost of the side cut was £24,340; of the locks, £53,280; of the buildings, £1,850; and of the dredging in the river below, £4,080; whilst the total cost of the works, including land and sundry items, amounted to £100,540.

L. V. H.

Poses Weir.

(Les Annales des Travaux Publics, November 1883, p. 985, 2 pl., 10 woodcuts.)

This weir possesses two special characteristics; namely, (1) a fixed bridge crossing the river at a height suitable for supporting the uprights of the weir, for facilitating the working, and for lifting the uprights out of water when the weir is open; (2) a special system of shutter for closing the weir.[1] The idea of employing a fixed bridge as a support, and for working a weir, is not novel, having been adopted by Vauban in 1680, at a bridge over the Meuse at Sedan. Movable foot-bridges have been used for a similar purpose at needle weirs. Mr. Tavernier, however, designed a scheme for a weir consisting of two iron bridges, resting upon high piers, from one of which iron frames were to be suspended and hinged; and the upstream bridge was to be used as a standpoint, from which the frames could be drawn up, and to which they could be fixed in a horizontal position. This principle has been carried out at Poses weir, on the Seine; and a rolling-up shutter, formed of a series of laths of wood jointed together, will close the spaces between the movable hinged frames. The bridge in course of erection at Poses consists of three girders supporting two platforms at somewhat different levels. The frames are hinged to the cross-girders of the down-stream platform. The other platform carries two tramway lines, on which the winches for raising the frames run. The frames rest, at their lower extremity, against the sill of the weir, and carry a movable foot-bridge, at 3½ feet above the upper water-level, from which the men can work the shutters. As the difficulties of working this system of weir are not increased to any extent by the depth of the passes, this weir has been given the same opening as the section of the river. The total width of the river is 800 feet, being composed of seven passes, each 99 feet wide, separated by piers 13 feet in breadth. The two passes of the left bank are the navigable passes; the two near the right bank are also deep passes, with sills 16½ feet below the upper pool; whilst the three centre ones, with

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[1] Minutes of Proceedings Inst. C.E., vol. lx., pp. 32, 61, and 62, and Pl. 4.

sills only 10 feet below the upper pool, are intended to regulate the discharge. The fall at the weir is 13 feet. The underside of the girders across the navigable passes has been placed 17¼ feet above the navigable high water, which is the full height fixed for the Seine; whilst the girders across the other passes have simply been placed high enough to put them above the flood-level. The level of the foot-way on the top of the lower girders corresponds with that between the higher girders, so the platform of the bridge is at the same level from end to end. The aprons of the passes are constructed of concrete, deposited under water, carried down to a solid foundation, with a paving of stone on the top; those of the deep passes have a thickness of 27¾ feet, and a length of 59 feet; whilst the overfall passes are 36 feet long and 34¼ feet thick. Large blocks of masonry were sunk to enclose the site of the aprons, in the place of the ordinary wooden dam. This system of weir could be constructed and worked for any height of weir that could be required in practice. It, moreover, possesses the following advantages: possibility of placing the foot-way out of the reach of any sudden flood; perfect safety for weir-keepers in working the weir, even at night; power of letting off water along the whole length of the weir; water-tightness of the shutters; facility for superintending and repairing the movable parts; saving of the labour of conveying the shutters and other parts to the shore; power of working the weir at any point along its whole length, independently of the rest, and without skilled labour; and, lastly, considerable simplification in the construction of the aprons, by the omission of the ironwork fastened on to them, as at Port-Villez weir.

L. V. H.

On the Construction of Canals in the Marsh Districts of East Friesland and the Central Ems Valley. By — Garbe.

(Deutsche Bauzeitung, 1883, p. 506.)

Burning off the marshes or bogs for the purposes of cultivation has been practised for centuries in the north of Germany, greatly however to the detriment of the climate, and with very unsatisfactory results from an economical point of view, as the only article which can be cultivated on the marshes after their being subject to this treatment is buckwheat. The marsh, after being burnt off from six to seven times, has to lie fallow for from thirty to fifty years, at the end of which period it is not nearly as productive as previously to the second time of burning.

The rich Dutch marsh plantations, however, show that another mode of cultivation is possible, and, in fact, the ground containing a great amount of nitrogen is quite capable of producing a more valuable crop, provided it be well drained, and, by the plentiful use of manure and sand, supplied with the failing constituents, viz., silicic acid, potash, and phosphoric acid. This improved condition of the ground is obtained by getting rid of the turf or peat, laying bare the sand beneath it, or by producing a layer of mould on the surface of the marsh. The peat, which generally varies in depth from 13 to 16 feet, is removed in layers of about 6 to 10 feet in breadth. The first layer, from 1 to 3 feet thick, is useless as a fuel; it is on removal cast aside on the already bared portion of the marsh, covered with a few inches of sand, and, by means of repeated ploughing, thoroughly mixed with the same. The stripped portion of the marsh is thus covered with a layer of loose soil which passes air and water freely through it, and accelerates the mouldering of the ground, at the same time protecting it from frost.

At a depth of 3 feet the turf which is met with forms an extremely good fuel; it is stripped off and left to dry on the surface of the marsh, after which it is removed in boats by means of the canals with which the land is intersected. These canals are constructed in such a manner that their water-level is from 6 inches to 1 foot below the surface of the sand, and thus about 4 feet 6 inches below that of the cultivated marsh. The whole canal system consists of main and secondary canals which are combined in different ways. The simplest system, and that generally employed in North Germany, where the moors are divided into a large number of small allotments, comprises a main canal with towing path on both sides, and secondary canals entering it at right angles, at intervals of 8 chains. Each consecutive two of these canals enclose on one side two allotments, whose depths measure 12·5 chains, and areas consequently 5 acres. The small channels are the property of the two owners whose land they divide, whilst the main canal belongs in common to the whole district. In this system the owner can begin removing his turf in the vicinity of the main canal, and need only begin the construction of the secondary canal bit by bit as he recedes. The great drawback to this kind of network is that all the secondary channels pass under the towing paths of the main canal, and have at the points of crossing to be provided with draw-bridges.

Another way of laying out the canals is that of constructing two main channels parallel to one another with cross channels, at intervals of from 40 to 50 chains, beginning close to one of the main channels and entering the other. Besides this system there is a great variety of others, in most of which, however, the secondary canals are placed at greater intervals, so as to avoid in a great measure the use of drawbridges.

In fertilising a marsh it is important, before definitely constructing the canals, to thoroughly drain the land at least three years in advance. This is done by means of a central drain cut along the centre line of the intended canal, and two smaller side-drains outside the towing-paths. The drains are cleaned out every six months, besides being annually widened and deepened, as far as permitted by the stability of the marsh, until the required section of the canal is attained. In many cases the cutting of the canals has been proceeded with too rapidly, without allowing the moor time to drain. This practice has, however, almost invariably resulted in extensive slips of the slopes which are generally made with a batter of 1½ to 1.

The cost of the earthwork (including all accessories) ranges, per cubic yard, from 1½*d.* to 2½*d.* for peat, and from 6*d.* to 7*d.* for sand.

The locks, which are as a rule necessary, have a length of 50 feet, and width varying from 13 to 14 feet. In the Abelitz-Moordorf canal they were constructed of stone at a cost of about £1,200. In most cases, however, they consist entirely of timber, so as to allow of any alteration which may in future become necessary.

The boats by which the turf is transported are 46 feet long by 11 feet 6 inches wide, with a draught of from 3 to 4 feet.

The canals in the domain of Lilienthal, in Bremen, differ materially from those above described. The vessels used on them are 30 feet in length, with a draught of 1 foot 8 inches. Instead of locks, the canals are, where necessary, provided with movable weirs, constructed of timber laths covered with leather, over which the flat-bottomed boats readily pass in either direction.

Another method of cultivating the marshes without previously removing the turf is to cut a number of drains, 16 feet in width, about a chain apart, the sand which is removed from these drains being cast upon the surface of the marsh to a depth of 4 or 5 inches. This layer of sand forms a protecting cover; which lets the water through, and which at the same time gives the requisite solidity for the growing of crops. This method is employed advantageously in cases where the turf does not exceed 5 feet in depth.

J. R. B.

On the Current-Meter. By F. P. Stearns, M. Am. Soc. C. E.

(Transactions of the American Society of Civil Engineers, vol. xii., 1883, pp. 301–338.)

A screw current-meter was used for five years in determining the flow of the Sudbury river, and appeared trustworthy. A new meter was then constructed with improvements suggested by experience. This new instrument has a frame surrounding the screw, and permitting the use of two end bearings for the axis. The friction is thus so much reduced, that the meter registers velocities of only one-fourth as great as the lowest indicated by the previous instrument. Two screws are provided 0·3 foot in diameter. The recording apparatus is above the screw, and indicates a half revolution. The instrument is mounted on a brass rod and has no rudder vane.

Details of the method of rating the meter are given. A track was erected over the Sudbury conduit, 140 feet in length. The recording wheels of the meter were put into and out of gear automatically at the ends of a 100-feet length. A regular speed was obtained by making the strokes of a bell, sounded by the car wheel, coincide with the ticks of a metronome. The time was taken by a stop-watch. The eight-vane screw began to revolve with a velocity of 0·104 foot per second; the ten-vane screw with a velocity of 0·094 foot per second; nearly 200 observations were made with each meter. The Author discusses the influence of the variations of velocity and direction in a stream, on the accuracy of the observations taken by the meter. Experiments in which the meter was moved irregularly showed that the revolutions for a given mean speed were greater than for uniform motion. Experiments with the meter placed obliquely to its direction of movement, showed that a considerable angle (11°) between the axis of the meter and the current, would not cause any important error.

A comparison is then made of current-meter and weir measurements of the flow in the Sudbury conduit. Measurements at a large number of points in the cross-section, gave a result agreeing closely with the weir measurement; moving the meter at a slow rate, so as to integrate the velocity at different parts of the current, also gave results agreeing with the weir measurement nearly. The effect of integrating too rapidly is to diminish the meter measurement.

The conclusion drawn from the experiments as a whole is, that the current-meter will give results accurate within 1 per cent., either by observation at a number of points, or by integrating, provided in the latter case the velocity of the meter is not more than $\frac{1}{20}$ that of the water.

The Author then discusses the cause of the depression of the maximum velocity below the surface, and attributes it to an upward flow at the sides of the channel, and a surface flow from the sides towards the centre.

W. C. U.

A New Self-Registering Tide-Gauge.

(The American Engineer, vol. vi., 1883, p. 221.)

This piece of apparatus has been in satisfactory operation at Fort Miffin, Delaware River. It was designed by Professor D'Auria, and constructed at a cost of only £13. It differs from ordinary tide gauges in that the cylinder or drum on which the paper is wound is turned by the rise and fall of the tide, while the pencil is moved in the direction of the axis of the drum by the clock, the relative duties of clock and tide being usually just opposite to this.

The float, which must have a minimum cross-section of 1 sq. ft., moves up and down in a box, the lower end of which is a few feet below extreme low-water mark. The water is admitted through a small aperture ½ in. in diameter. This is an important point, since the float is practicably unaffected by common waves, even of considerable magnitude. The float is suspended by a chain which passes over a pulley, 3 feet in diameter, on the spindle of which is a brass drum 3 in. in diameter and 27 in. in length. Thus one turn of the drum is equivalent to a rise or fall of 9 ft. in the tide, the scale being 1 in. to the foot. For a greater variation in the tide the chain attached to the float may take more than one turn on the pulley. This of course involves the movement of the pencil over the joint in the paper on the drum, but by first gluing one end of the paper to the drum, and having sufficient length of paper to allow the second joint to be made clear of the first (by overlapping it), not only the record may be taken off intact, but the pencil is found to pass over the joint without being in any way affected by it. An ordinary eight-day clock draws the pencil across the drum, by means of a waxed silk thread, at the rate of one inch in an hour. The pencil must thus be reset by being drawn back to its starting-point by hand once in about twenty-four hours. Inasmuch as the curves are continuous, one paper will last several days, the one shown in the illustration being a record from July 4th to July 10th, 1882.

Altogether the arrangement appears to be a very cheap and simple one, and at the same time quite accurate enough for its required purpose.

H. S. H. S.

Works of Consolidation executed upon Sicilian Railways.

By A. Billia.

(Giornale del Genio civile, 1883, p. 301.)

This Paper gives an account of very extensive and costly works carried out upon the Catania-Licata and Palermo-Porto Empedocle railways, which pass through ground of a very treacherous character.

The geological strata through which the lines pass are described. The principal, and at the same time the worst, are the marl formations of the lower miocene and upper eocene. These earths swell when wet, and become of a pasty consistency, and unless the fall of the ground is very slight they begin to slip. In dry weather cracks, several inches in width and of considerable depth, open out, which, when rain falls, admit the water, and, aided by thin strata of sand, which are always found in these earths, allow it to penetrate underneath the slipping ground, and cause further and more extensive movements. In some places the landslips are aggravated by the percolation of water from a distance. So treacherous is the nature of the ground, that it is quite barren of trees, and also of human habitations. Cuttings in this ground must have flat slopes, and these require costly protective works to prevent slipping. Embankments formed of the same material are still worse, for they absorb the rain, and even in the hottest weather do not dry up; they become incapable of bearing their own weight, and still less the passage of trains, unless provided with draining and retaining works of a more costly description even than those required for the cuttings.

Another difficulty is caused by the action of the water in the streams. The banks of these are so soft and pliable that they are constantly being washed away, so that in the course of a few years a little brook expands into a ravine, with banks constantly slipping in, and a bed formed of materials which offer no resistance to erosion.

Out of a length of 120 miles of railway, 80 miles pass through ground of the above description, and there is not a cutting or an embankment in which special works have not been required, either owing to the line traversing a landslip, or to hold up the earth in the cuttings and banks, or to protect the works from the destructive action of a stream or torrent. Works of varying character, and on the largest scale, have been constructed.

Covered Ways and Retaining-Walls.—These were used extensively at first, but have since been abandoned. The former, if properly constructed, and accompanied by efficient drains, form an excellent protection to the road; but the expense is excessive, and the same results can be obtained by other methods at much less cost. Retaining-walls are ill-adapted to hold up the sides of cuttings, as they have no effect in removing the principal cause of slips, namely, the saturation of the soil with water, which continues to take place, and frequently occasions the destruction of the wall.

Drains.—When, from a careful consideration of all the circumstances, such as the geological character of the soil, the positions of the various springs, and so on, it has been ascertained that the movement of great masses of earth is due to the action of subterranean water in forming a slippery surface between the strata, a system of drains is very effective in arresting the movement. One or more longitudinal collecting drains should be formed, at such a depth as to intercept all the underground water which produces the slips, and other transverse drains should be made, so as to carry off the water thus collected. These drains may either be constructed in open cutting or in tunnel. In the latter case shafts are sunk, at intervals of from 15 to 65 feet, to such a depth as to reach below the water, and these shafts are then connected by tunnelling. The drains formed in open cutting were generally carried down to a depth of from 1½ to 3 feet into the impermeable ground below the slip. They were made from 3 feet 3 inches to 4 feet wide. The bottom was covered with about 1 foot of concrete, concave on the upper surface; two small side walls were built to a height of about 1 foot, that on the uphill side of dry stones, that on the downhill in mortar, leaving a channel between them, which was covered with rough stones. The excavation was then filled in, to within about 3 feet of the surface, with large stones. A layer of small stones was then added, and the remainder filled in with rammed earth. The sides of the excavation should be vertical. These open cuttings were adopted down to depths of 40 or 50 feet. At greater depths, and sometimes for special reasons at less, the shaft and tunnel system was used. These were constructed in a very similar manner; the shafts were rectangular, the best size being about 4 feet by 4 feet. In the transverse drains the two side walls were generally built in mortar, and the stone filling was carried up from 3 to 6 feet above the channel.

It should be noted, in reference to the tunnel system, that where a large and solid mass is sliding down the plane surface of an impermeable stratum, which is rendered slippery by a film of water, the shafts can be separated by long intervals; but such cases are rare, and it is much more common to meet with those in which the whole moving mass is rendered incoherent by water percolating through it, and it then becomes necessary to put the shafts at short distances apart, to intercept and drain away the water.

Works for Drying the Slopes of Banks and Cuttings.—In many cases the means described above were not sufficient to prevent the slopes from slipping, but numerous other drains had to be made in various directions. Before the lines were commenced it was not anticipated that the ground would be so bad, and it was not till after the works were in progress that repeated slips showed that special measures must be resorted to, and these were therefore of a remedial rather than a preventive nature. Dry stone counterforts, let into the slopes, were applied on a large scale, both in cuttings and banks. They were placed at intervals of from 20 to 40 feet, were from 4 to 6½ feet broad, with vertical sides, and were carried far enough into the slopes to pass through the whole mass of moving earth. The front face was made to the slope of the cutting, the bank formed in steps, of from 6 to 26 feet. In special cases, in banks, these counterforts were carried the full height of the bank, with vertical backs. They were founded on beds of concrete, about 1 foot thick. In some cases drains were put in at the back, from counterfort to counterfort. Generally they drained into the side ditches of the formations in cuttings, but sometimes were too deep for this, and a masonry drain was built below the formation. Frequently counterforts were built opposite to one another on both sides of the cutting, and carried under the formation, so as to meet at a central drain. This plan is a very good one in cases where the formation bulges up, owing to the sides of the cutting sinking in a vertical direction without apparent horizontal movement. Where the weight of banks caused the ground at the sides to bulge up (in which case the banks always spread out) frequent cuts were made in the moving mass down to firm ground, in which a drain was formed, and the cuts were then filled in with stone. All masonry foundations in this sort of ground were carried down right through the treacherous soil. The spaces between abutments were filled in with dry stone, and arches were built at several heights between the abutments.

The counterforts above described were not sufficient, as a rule, to prevent the slopes of banks and cuttings from slipping. It was generally found necessary to remove either the whole or a considerable part of the slope, and replace it with the best material that could be found (in default of better, the surface-soil from the neighbourhood was used), which was spread in layers of about 1 foot thick, watered and rammed. Between this new earth and the old from 1½ to 2½ feet of broken stone was placed upon benches cut out to receive it. The water was drained away either by the dry stone counterforts, or by special drains placed at intervals of not more than 66 feet. Drains were also made on the external slopes, and in many places the slopes were formed with benches about 5 feet wide, and at vertical distances of about 20 feet; drains were laid along the steps to carry off rain-water. At first these drains were made of masonry, and the benches were covered with a layer of concrete or paving in mortar, but it was soon found that a certain amount of settlement was unavoidable, and that masonry cracked in consequence of it. This plan was therefore given up, and the drains were made of tiles overlapping one another. Of course they had to be laid with a good fall.

Besides the drains on the formation and on the benches, masonry drains were built along the tops of all the cuttings, and at the feet of many of the banks, of sizes proportionate to the areas of land draining towards the line, and all watercourses discharging into these drains were lined with masonry. In fact, all possible means were adopted to prevent the water from flowing into the cuttings, and from soaking into the ground adjacent to the line. In places where the ground upon which the banks were built was liable to be saturated with water, small drains were laid at a depth of from 3 to 6 feet below the side drains, so as to intercept the water in the soil, and prevent it from reaching the base of the embankments. As it was found that the banks were damaged by water passing through the ballast being retained for a time in the bank, and then forcing its way out and washing away the earth with it, tile drains were laid across the bank, and far enough below the surface to ensure them against being damaged by the passage of trains.

An attempt has been made to improve the character of the soil by planting trees, such species being selected as have deep roots and abundant foliage. It is thought that these will absorb the moisture when the ground is wet, and at the same time will, by protecting it from excessive heat, hinder the formation of cracks in dry weather.

The Author concludes by saying that it is perhaps premature to judge of the permanent effects of the works executed, but they have so far been attended with satisfactory results, and they represent the best systems which four years' experience on the most extensive scale have led the engineers to adopt.

The Paper is illustrated by a number of drawings of the more important protective works, and Tables are given showing the cost of many of them.

W. H. T.

The Drachenfels Railway. By C. Schmid.

(Deutsche Bauzeitung, 1883, pp. 349–350.)

This mountain railway was constructed by the German Steam-Tramway Company, and was opened on 17th July, 1883.

The station is just behind the Königswinter Station of the Rhine Railway, and the line runs pretty straight up the Drachenfels, though with a view to reduce the amount of earthwork, and to avoid expensive construction, there are some curves of 11 chains, and one of 10 chains radius. On leaving the station, the line is level for about 2½ chains, then it rises in a gradient of 1 in 8, and after that there are various changes of slope, from a minimum of 1 in 10 to a maximum of 1 in 5. The total length of the line is about 1660 yards, and the rise 242 yards. The permanent way is on the Riggenbach system, like the Rigi Railway, and the gauge is 1 metre (3·28 feet). The rack between the rails is of steel, with two rolled cheeks of ⊏ section; the cogs are of wrought-iron, and the whole weighs 110 lbs. per yard. The rails are of steel, in lengths of 29½ feet, and are 4¼ inches high, 3½ inches wide at foot, 2 inches at the head, with ⅓ inch web, and weigh about 50 lbs. per yard. The cross-sleepers (iron) are about 6 feet long, and laid at intervals of 1 metre from centre to centre, and at every 50 metres there is a special arrangement for preventing a lateral displacement of the rack. The engines are 180 horse-power, and weigh about 18 tons each; the diameter of the driving-wheel is 3 feet 5 inches, and the number of teeth 33. There are seven trains daily up and down, which perform the trip in from twelve to fifteen minutes.

The standard cross-section of embankments gives a width of formation 15½ feet; the ballasting is 9¾ inches thick in the centre, and 13½ inches at the sides. In cuttings with side slopes, 1 to 1, the width of formation is generally 9 feet. The total amount of earthwork was 299,000 cubic yards, and it cost about 7*d.* per cubic yard, the soil in general being firm clay.

Special care was taken to drain the base of the embankments, and to carry off the surface-water on the mountain sides by catch-water-drains; the bases of the embankments were stepped in the usual manner.

Longitudinal and cross-sections are given of a viaduct of ten 18-feet spans, and a similar one of eight spans was also built on a very steep slope of the mountain.

Special mention also is made and cross-section given of a masonry culvert in a deep gorge crossing the railway at an angle of 50°, the line having a gradient of 1 in 5½, and the culvert itself having a fall of 1 in 3·6. For all the masonry constructions trachyte, a porphyritic stone, was used, which was obtained from a neighbouring quarry, as the trachyte of the Drachenfels contained so much felspar as to render it unsuitable. The mortar employed was composed of one part cement, four lime, and ten sand.

For ordinary masonry, about 14*s.* per cubic yard was paid, but for special arch-work, where scaffolding was necessary, the contract price was 3*s.* per cubic yard extra. The cost of the whole line, exclusive of purchase of the land was about £10,000.

W. H. E.

On the Effective Work of Locomotives, and their Consumption in Water and Fuel. By Professor A. Frank.

(Organ für die Fortschritte des Eisenbahnwesens, 1883, p. 77.)

The writer was employed by the railways of Alsace-Lorraine to make a series of experiments, with the view of determining the consumption of fuel on their locomotives. For this purpose it was resolved to ascertain the amount of water evaporated per kilogram of coal, and then to measure accurately the water used both with locomotives alone and complete trains. For this purpose gauge-glasses were fixed on each side of the locomotive and of the tender, and so arranged that the water-level could be accurately taken, and thus the consumption determined. The waste-water from the injector was also collected and measured. As the water evaporated represents a definite quantity of work done, this gave an opportunity of comparing the effective work of engines under various circumstances in comparison with the water used.

The resistances to an engine when running without steam have been considered elsewhere.[1] When the engine is under steam, these are increased by the facts that the slide-valves work under the steam-pressure, and that this pressure is also brought upon

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 366.

the eccentric straps, connecting-rods, ends, &c. Let p be the mean pressure in the valve-chest, o the area of the valve, and f the coefficient of friction, then the friction of the valve is $p\,o\,f$. Let s be the travel of the valve per revolution, and D the diameter of the driving-wheel; then the work done on the two valves per metre run is given by

$$S_1 = \frac{2\,p\,o\,f\,s}{D\,\pi}.$$

The thrust $p\,o\,f$ needed to move the valves is taken by the two eccentric-straps. Let E be the diameter of these, and f_1 the coefficient of friction; then the work done on friction in the two eccentric-straps per metre run is given by—

$$S_2 = \frac{2\,p\,o\,f\,f_1\,E}{D}.$$

With regard to the driving gear, there has to be considered the friction between the cross-head and the slide-bars, between the cross-head and the connecting-rod, between the connecting-rod and the crank-pin, and between the coupling-rods and their pins. Let r be the radius of the crank, l the length of the piston-rod, d_1 the diameter of the cross-head journal, d_2 that of the connecting-rod bearing, and d_3 that of the coupling-rod bearing, f the coefficient of friction for longitudinal motion, f_1 ditto for rotary motion, P the mean pressure on the piston. Then there result the following equations for the work done per revolution of the driving-wheel:—

Friction between cross-head and slide-bars, $L_1 = \frac{f\,P\,r^2\,\pi}{l}$;

Friction between cross-head and connecting-rod, $L_2 = 2\,f\,P\,d_1\,\frac{r}{l}$;

Friction between connecting-rod and crank-pin, $L_3 = f_1\,P d_2\,\pi$.

For the friction of the coupling-rods distinction must be made between four-coupled and six-coupled engines. In the first, half the pressure, or $\frac{P}{2}$, comes on each coupled axle; and therefore,

$$L_4 = f_1\,P\,d_3\,\pi.$$

In the second, one-third of the pressure only comes on each coupled axle, and the sum of these pressures on the driving-axle. If d_4 is the diameter of the bearing for the latter,

$$L_4 = \tfrac{2}{3}\,f_1\,P\,\pi\,(d_3 + d_4).$$

Dividing the sum of these four values ($L_1\,L_2\,L_3\,L_4$) by the total work, $L = 4\,r\,P$, the work done in friction can be compared with the whole work done on the engine. The various symbols used must of course have the values belonging to the special engine considered. For a particular six-coupled goods-engine, the writer calculates that the work thus done on friction due to the steam, is only about 4 per cent. Adding this to the work required for overcoming other resistances, as described in the former abstract, the Author obtains a general expression for the work done by an engine in taking a train between any two stations at a given speed, over any given curves, and with any number of stoppages, &c. Numerous experiments were made, both with goods- and passenger-engines, to test this expression; the coefficient of resistance *m* having been determined as in the former abstract. The length of the run and the weight of water evaporated were always taken, and thus the work done per kilogram of water could be determined.

Some of the results are given in the following Table :—

TABLE of RESULTS.

Number of Experiment.	Kind of Engine.	Vehicles in Train, as under—					Water Expended.	Average Speed.	Work Done.	Work per Kilogram of Water.
		Carriages.	Vans.	Covered Wagons.	Empty Trucks.	Loaded Trucks.				
							Kilograms per sec.	Metres per sec.	HP.	Kilogram-metres.
1	Passenger	..	..	..	..	..	0·399	7·06	80·5	15,166
2	,,	..	..	..	..	..	0·406	6·76	85·4	15,745
3	,,	..	..	..	..	..	0·244	10·83	44·0	13,547
4	,,	..	..	..	..	..	0·273	10·50	55·5	15,245
5	,,	..	..	..	..	..	0·278	11·48	57·6	15,525
7	,,	..	..	..	..	..	0·375	13·20	76·0	15,199
9	,,	..	..	..	..	..	0·486	16·60	118·1	18,214
11	,,	..	..	..	..	..	0·557	18·20	139·2	18,723
13	,,	..	..	..	..	..	0·523	18·20	138·5	19,651
14	,,	..	..	..	..	..	0·590	18·40	156·6	19,926
16	,,	6	1	..	..	..	0·543	12·03	136·8	18,877
17	,,	6	1	..	..	..	0·959	17·07	244·1	19,061
1	Goods .	..	..	..	..	..	0·280	8·60	46·46	12,420
2	,, .	..	..	..	..	..	0·274	8·88	57·66	15,786
3	,, .	..	..	..	..	..	0·287	9·54	51·77	13,519
4	,, .	..	..	..	..	..	0·341	9·78	65·35	14,382
6	,, .	..	1	9	19	4	0·491	8·00	171·70	26,253
7	,, .	..	1	..	..	41	0·560	7·04	179·30	24,014
8	,, .	..	1	..	..	41	0·566	7·26	189·80	25,126

The experiments embrace, as will be seen, very different conditions; the speed with the passenger-engine varying from 7·06 metres per second to 18·4, and the power expended from 44 to 244 HP.; and in the goods-engine to nearly the same extent.

The three last columns of the Tables enable a law to be laid down on the relation of effective work to water expended. Let W be the water expended in kilograms per second, and N the

HP. expended in overcoming resistance. Take the first as ordinates, and the latter as abscisses, and plot the results of the experiments. It will be found that they approximate to two straight lines; that for the passenger-engine corresponding to the equation

$$W = \frac{N}{300} + 0\cdot1,$$

and that for the goods-engine to the equation

$$W = \frac{N}{500} + 0\cdot18.$$

They give the same water expended for 60 HP. (viz. 0·3); for greater values of N the goods-engine shows the better results; for less values the passenger-engine.

If x be put for the effective work in kilogrammetres per kilogram of steam evaporated, there is obtained the relation (since 1 HP. = 75 kilogrammetres)

$$x\,W = 75\,N.$$

Whence result, using the two formulas above, the two following equations—

$$\text{For passenger-engines } x = \frac{22{,}500\,N}{N + 30};$$

$$\text{For goods-engines } \quad x = \frac{37{,}500\,N}{N + 90}.$$

From these formulas may be shown clearly how small is the influence of the speed on the useful effect, and how this effect increases with the work done per second.

Of course at very low speeds the cooling of the cylinder would diminish the useful effect, and at very high speeds the loss of pressure in the cylinder, and the quantity of priming water, would have a similar tendency. But, in practice, these elements are not greater than the ordinary errors of observation. Thus in Nos. 13 and 16 of the Table, where N = 138·5 and 136·8, the water expended is 0·528 and 0·543 respectively, or very nearly equal; whilst the speed is 18·2 in the one case, and 12·03 in the other. The above equations may therefore be used quite independently of the speed. With their help it is easy to calculate the work done, and water expended, in sending a known train at a known speed over any particular length of line, on which the curves and inclines are given. Knowing the water expended, the fuel burnt is easily obtained, since the relation between them remains almost constant as long as the quality of the fuel and the conditions do not change. Elaborate experiments made by Wöhler in 1879, and published in the "Centralblatt für Bauverwaltung," 1882, show that, on an average, the weight of water evaporated is seven times the weight of coal burnt.

From these results, the conclusion is drawn that it is desirable to give to each engine the heaviest train it will draw, not only because it is thereby better employed, but because (as seen by the form of the equations above) the useful effect increases with the work done. Of course the engine must not be overloaded, so as to cause too much priming, &c. Again, a succession of rising and falling gradients have a very small effect on the work done, provided that the speed in descending has not to be checked by brakes. Of course, however, the load to be put on an engine must be calculated with reference to the steepest gradient it has to surmount, and the maximum resistance it may encounter on that gradient. The resistances due to curves and gradients respectively are known, and in each railway a maximum value for the sum of these resistances should be assumed, taking the place of what is now called the ruling gradient.

Again, the result that the useful effect is practically independent of speed has important consequences. As the speed diminishes, the resistance of the air diminishes in a much higher proportion, and the tractive power at the same time increases. Hence, lowering the speed is very effective in overcoming great resistances, although a limit is of course set to this by the limited adhesive force between tires and rails. Taking the coefficient of friction as 1 by 7, the limit of tractive force for the goods-engine in the above experiments was 5,500 kilograms, and for the passenger-engine 3,143 kilograms. The greatest power of the two engines was, for the former, 25,500 kilogrammetres per second, and for the latter 21,000. Dividing these quantities by the former, the minimum speed for the goods-engine is 4·5 metres per second, and for the passenger-engine, 6·7. This minimum speed being fixed, and the other elements of the question known, it is easy to find an equation for the greatest number of vehicles that can be hauled by a given engine over a given line. The results are worked out in the following Table, in which the gradients are those on a straight road, and must be lowered proportionately if there is a curve at the same place.

Vehicle.	Minimum Speed.	Maximum Gradient.							
		$\frac{1}{500}$	$\frac{1}{400}$	$\frac{1}{300}$	$\frac{1}{200}$	$\frac{1}{150}$	$\frac{1}{100}$	$\frac{1}{80}$	$\frac{1}{50}$
	Metres per sec.								
Carriages, express trains	14·0	..	..	11·3	8·2	6·1	3·3	2·0	..
„ ordinary „	10·0	..	..	22·0	16·3	12·8	8·2	6·1	2·5
Covered goods-wagons, loaded	4·5	62·7	56·2	48·1	36·5	29·2	20·6	16·6	10·0
Covered goods-wagons, empty	4·5	..	..	..	..	67·5	47·8	38·6	23·2
Open wagons, loaded .	4·5	73·3	65·6	56·1	42·6	34·1	24·1	19·4	11·6
„ empty .	4·5	..	..	..	..	..	69·8	56·6	34·2

In the case of a level road, the same equations give the following values for the numbers of vehicles that can be hauled at given speeds:—

—	Speed.	Number of Vehicles.
	Metres per sec.	
Carriages, express . .	20·0	8·0
„ ordinary .	16·0	18·8
Covered wagons, loaded	7·5	61·7
Open wagons, loaded .	7·5	72·5

These figures agree well with experience, and show how rapidly the admissible load diminishes as the speed and gradients are increased; and also the great importance of noting whether the wagons are loaded or empty. Although taken from particular experiments, the equations are general, and may be used for solving any questions upon the movement of trains over railways.

W. R. B.

Experiments on the Resistance of various classes of Rolling-Stock on Railways. By Maschinendirector BERGK, Chemnitz.

(Der Civilingenieur, vol. iv., 1883, p. 209.)

The Saxon State Railways include a number of lines with curves down to 170 metres radius (557 feet 7 inches), on which, according to the regulations for the German railways, only rolling-stock with a correspondingly short wheel-base is allowed to run. The inconveniences attendant on this limitation led to the adoption of a small number of wagons with flexible wheel-base—the axles being free to move and not connected with each other by a bogie frame—which have been in use about ten years. These answered their purpose very well for moderate speeds, but were found unsuitable for higher velocities, and the increased demand for the latter resulted in a number of experiments being undertaken with rolling-stock, the axles of which were constructed in various ways. The outcome was the adoption, after careful trial, of two systems of flexible wheel-base, in addition to that already mentioned, both of which the author considers peculiar to the Saxon State Railways, and which gave satisfactory results. One of these systems applies to six-wheeled, the other to four-wheeled vehicles.

In the six-wheeled vehicles, the two end axles with their boxes are so constructed as to allow them to assume a radial position in traversing curves, this being effected by allowing the axle-boxes to slide longitudinally, while at the same time the bearings are free to oscillate about vertical pivots secured to the axle-box casing.

The central axle is connected with and supports a strong wrought-iron frame, on which the wagon rests; this frame is free to move laterally, being guided by angle-irons attached to the main frame of the vehicle.

By means of a peculiar arrangement of levers and tie-rods, the end axle-boxes are so connected with the central frame that the three axles always converge radially towards the centre of any curve which is traversed.

The central frame is in some cases also constructed so that it is supported by the main frame, and has no load to carry.

In the four-wheeled vehicles, the frames to which the axle-box guides are attached, are pivoted, so as to form a kind of bogie, but do not carry any of the load, the main frame being supported in the usual way from the axle-boxes by means of springs, the connection of the latter with the axle-boxes being, however, so arranged as not to interfere with the motion of the bogie.

The vehicles are found to run more smoothly than otherwise when the bogie frames are connected by tie-rods and a bell-crank lever pivoted to one of the main frames, in such a manner that the axles converge or diverge symmetrically about a line drawn from a point central between the two frames to the centre of the curve traversed; when both bogies are free to move independently, on entering a curve the trailing axle adjusts itself in a radial position much more energetically than the leading axle.

After both the systems referred to had been in use several years, experiments were undertaken with the object of determining the relative resistance on curves of vehicles with flexible wheel-base of the constructions referred to, as compared with those having a rigid wheel-base.

For this purpose an experimental carriage, containing all the necessary apparatus for registering the various quantities to be observed, was prepared. All the recording instruments were automatic, the resistance, velocity, and work done being registered in the form of curves.

The Author describes the mechanism of the apparatus used, with the assistance of diagrams, at some length.

The rolling-stock used for the experiments consisted of six four-wheeled passenger coaches, with a wheel-base of 5 metres (16 feet 4·8 inches), and four six-wheeled goods wagons, with a wheel-base of 7 metres (22 feet 11·52 inches), constructed on the systems previously described, but arranged so that in both kinds of vehicle the end axles could be made rigid, and the connections between the bogie-frames used or not at pleasure; six four-wheeled goods wagons with a rigid wheel-base of 4 metres (13 ft. 1·44 in.); six four-wheeled goods wagons with a rigid wheel-base of 3·05 metres (10 feet), and three eight-wheeled goods wagons with American bogies and a wheel-base of 5·485 metres (17 feet 11·39 inches).

The experiments took place on curves of 1148, 1312, and 1476 feet, with a uniform gradient of 1 : 100, and at velocities of 20 and 30 kilometres (12·42 and 18·63 miles) per hour.

The results showed that the four-wheeled vehicles of 4-metre wheel-base offered less resistance with a flexible than with a rigid wheel-base, and that when the bogie-frames were coupled, this resistance was less than when the frames were free; on the sharpest curve it was lower by 51·4 per cent. than with a rigid wheel-base, with the six-wheeled vehicles; on the other hand, the best results were obtained when the axles were disconnected and movable.

G. R. B.

On a New Unit of Work for the Comparison of Locomotives.

By R. Abt.

(Glaser's Annalen für Gewerbe und Bauwesen, vol. xiii., 1883, p. 193.)

The Author complains of the want of a universal and scientifically constituted unit for the work done by locomotives. After describing at length the different measures in vogue, and condemning them all as deficient for purposes of general and accurate comparison, he comes to his subject—the formation of a unit applicable in all cases.

In order, in forming a new unit, to start on a proper basis, one must keep to the scientific meaning of the term work, and the elements in the expression must be those used in dealing with railways, *i.e.*, the hour as the unit of time, the kilometre as the unit of distance, and the ton as the unit of weight.

A unit formed from these elements is theoretically correct, in common with those of horse-power and metre-kilogram, and has the additional advantage of obviating the necessity of laborious calculations. The Author calls this unit, which expresses the work done by a locomotive during one hour in drawing a weight of 1 ton over a distance of 1 kilometre "locomotive-power" (*Locomotivstärke*). As the speed per hour is always given, the product of the tractive force in tons multiplied by the speed expressed in kilometres gives the number of locomotive-power of any engine.

According to the above definition, the relation existing between locomotive-power and horse-power is—

$$1 \text{ LP.} = \frac{1000 \times 1000}{75 \times 3600} = \frac{100}{27} = 3 \cdot \dot{7}0\dot{3} \text{ HP.};^{1}$$

and inversely,

$$1 \text{ HP.} = \frac{75 \times 3600}{1000 \times 1000} = \frac{27}{100} = 0 \cdot 27 \text{ LP.}$$

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[1] 1 HP. in the metric system is equivalent to raising 75 kilograms 1 metre during one second, and bears the ratio to an English HP. of 75 : 76·041.

Examples showing the application of the unit:—

The express engines of the St. Gothard railway (series B) have a mean tractive force of 2·5 tons, and are, when exerting this, capable of maintaining a speed of 35 kilometres per hour. Their work is thus—

$$2{\cdot}5 \times 35 = 87{\cdot}5 \text{ LP.} = 324 \text{ HP.}$$

The engines of the Rigi have a tractive force of 5·4 tons, with a speed of but 5 kilometres per hour. Their work thus amounts to—

$$5{\cdot}4 \times 5 = 27 \text{ LP.} = 100 \text{ HP.}$$

These engines, therefore, in spite of exerting a tractive force more than twice as great as that of the St. Gothard engines, do less than a third of their work.

The Author has determined the locomotive-power of a large number of engines, and gives a Table in which he expresses it in terms of the cost, weight, volume of cylinders, grate-surface, &c.

The Author concludes by pointing out that by the use of his unit of work the maximum loads for different engines, for any given speed and gradients, are readily arrived at; he also dwells upon the advantage gained by being able to determine the consumption of coal per locomotive-power, instead of per kilometre, and generally of being able to ascertain the performance of different engines, the effect of different kinds of fuel, consumption of steam in working continuous brakes, &c.

J. R. B.

Endless-Rope Tramways in San Francisco, California.

(The Railroad Gazette, 23 Nov. 1883, pp. 767–771.)

In continuation of the recent Paper[1] by Mr. William Morris, on "Wire-Rope Street Railroads in San Francisco and Chicago," the following particulars are abstracted with respect to the distinctive features characterising the Market Street and connected lines of endless-rope tramway, which are the most recent and by far the most extensive of the street railroads in San Francisco, having been opened on the 22nd of August, 1883.

The main tramway runs along Market Street, the principal thoroughfare of San Francisco; out of which at its upper end run branches to the right along McAlister Street and Haight Street, and to the left along Valencia Street. The endless wire-ropes are all of crucible steel, 4½ inches circumference,[2] and weighing 2½ lbs.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxii., pp. 210-218.

[2] Misprinted "diameter" in the original.

per foot; that in Market Street is over 24,000 feet long, that in McAlister Street over 26,000 feet, and the two others each over 20,000 feet. They are lubricated with castor oil, the use of tallow and other animal fats being avoided. The gradient in Market Street is 3½ per cent., or 1 in 29; in Haight Street it is 12½ per cent., or 1 in 8, at the steepest part.

The grip, or flat plate which is fixed on the leading truck of the tram-car and passes down through the central ¾-inch slot in the street to lay hold of the rope running beneath, is so constructed by Mr. Henry Root, the engineer of the line, as to be vertically over the rope; the pull of the rope is thus central both upon the grip and upon the car, thereby obviating the objectionable twisting strain that is thrown upon the shank of the L-shaped grip in use on previous roads, where the draught is consequently to one side. The grip-plate is of steel, and is in three pieces; namely, two flat bars fixed fore and aft, serving as guides for a middle bar which slides vertically between them. The rope is gripped by a pair of jaws, between which it enters at one side when they are opened to lay hold of it; the lower jaw, which has a small chilled-iron grooved-roller fixed fore and aft of it, is carried on the two fixed bars at a constant depth below the car-truck, and the upper jaw is carried on the sliding bar. When the upper jaw is gradually depressed by the conductor's toggle-jointed hand-lever, it first presses the rope hard upon the fore and aft rollers of the lower jaw, before the rope is gripped fast between the two jaws; the motion of the running rope is thus imparted to the car gradually, without jerk or jar. Wood has been tried for the jaws, and so has brass; but soft iron is found to be as good. This grip works very satisfactorily indeed.

The depressing pulleys over the rope, for holding it down wherever the line becomes concave or hollow, are each mounted on the outer end of an arm swivelling upon a vertical axis; the arm is about 6 feet long, and is bent horizontally so as to slant across the rope at a slight obliquity. The grip-plate on approaching presses sideways against the slanting arm, and thereby swings aside the pulley ahead, clear out of its way; as soon as it has passed by, the pulley is swung back again into its central position over the rope by a counterpoise attached to its arm.

The grooved supporting pulleys underneath the rope are placed every 30 feet along the road; they are 13½ inches diameter at the bottom of the groove, and are cast solid with their axles, which are 1¼ inch diameter, with bearings 2¾ inches long, running on lignum-vitæ bushes.

The rope runs in a concrete trough, made by filling in with concrete the 3-feet spaces between transverse wrought-iron frames or "yokes," which connect the tram-rails rigidly with the central slot-rails. The transverse frames are old T-rails bent to shape, head outwards. The trough is supported, at 9-feet intervals, on concrete piers 16 inches thick; and is covered in above with concrete, on which is laid the road paving.

The engine-house, from which are driven the ropes working the Market Street and Valencia Street lines, stands at the junction of these two streets, where there is a curve slightly downhill from Market Street, of 80 feet radius, and containing an angle of 55°. Up this curve the returning cars from Valencia Street are carried 120 feet by an auxiliary rope, driven from the same engines as the main ropes. The auxiliary rope is guided round the curve by fifteen upright conical rollers, standing with their smaller ends uppermost; when running idle, it settles down to the lower and larger ends of the rollers; but when engaged in the grip, it is thereby lifted to the top of each roller in turn, at which height there is clearance enough for the grip to pass by without touching the roller. On approaching the curve, a slight bend outwards in the line of the tramway swerves the car sideways far enough for the grip to clear itself from the Valencia Street rope; the car's momentum has then to carry it about 8 feet, till the grip lays hold of the auxiliary rope. The opening and closing of the grip are done by the conductor upon the car, on arriving at the proper points. A second swerve and gap occur at the further end of the curve, where the grip quits the auxiliary rope and lays hold of the Market Street rope. While the speed of the main ropes is 8 miles an hour, that of the auxiliary rope is only 4; its tension also is much less, as it has to convey only one car at a time round the curve, while each main rope is conveying several cars at once on different parts of its route.

Round the short curve by which Haight Street branches off from Market Street, the cars of that branch run in either direction by their own momentum. They are turned off from the main line to the branch by a switch that shifts both the tram-rails and the central grip-slot together for the curve. As a safeguard against any accident through forgetting to release the main-line rope from the grip before the car for the branch arrives at the switch, a roller 6 inches diameter and 8 inches long, carried upon an arm on a rocking shaft, is placed in the rope-trough, 30 feet in advance of the switch. So long as the switch remains closed, the roller stands upright at one side of the main-line rope, and clear out of the way of the grip; but the hand-lever by which the switch is opened for the branch brings the roller at the same time down upon the rope, and depresses it low enough for the grip to pass free over the roller, provided the rope has already been released from the grip. Should the release have been forgotten by the conductor on the car for the branch, the grip retaining hold of the rope will draw the roller up and thereby simultaneously close the switch, so that the car will continue along the main line, instead of turning off to the branch. The Haight Street rope is driven from the same engine-house as the Market Street and Valencia Street ropes. The returning cars from the branch, after dropping the Haight Street rope and running round the curve on to the main line, have to pick up the main-line rope, which is raised for the purpose by means of a conical roller underneath.

6 inches long, and tapering from 6 inches to 2½ inches diameter. The roller turns on a rocking arm; and being lifted at the right moment by a chain from the surface of the street, it raises the rope with a sort of semicircular movement, first drawing it sideways clear of the grip, and then delivering it from the smaller end at the proper height to enter sideways between the jaws of the grip, which is thus enabled to grasp it. This arrangement is found to answer perfectly, and is very convenient.

At the bottom of Market Street the cars are turned round, end for end, upon a turntable 30 feet diameter, which is rotated slowly by the rope itself, through the intervention of a paper friction-wheel.

The ropes are each driven by two vertical pulleys, 12 feet diameter, placed in line, having their rims faced with wood blocks, 2 inches thick and set on end; maple is used, but beech is supposed to be better. The rope takes only three-quarters of a turn round each driving pulley, and is kept tight enough upon them by passing half round a vertical tightening pulley of 13 feet diameter, which is mounted on a carriage pulled horizontally by a heavy weight; the stretch of the rope is thus taken up, and a uniform tension maintained.

In addition to ordinary brakes on the wheels of the cars, a slipper brake is employed, consisting of a long block of wood, pressed down on each tram-rail by a toggle-joint powerful enough to lift almost the weight of the car. By this means a car weighing 4½ tons, and carrying also 4½ tons load, can be stopped in 10 feet from a speed of 8 miles an hour.

A. B.

Best Motive-power for Tramways.

(Engineering News and American Contract Journal, 24 Nov., 1883, p. 565.)

At the recent annual meeting in Chicago of the American Street-Railway Association, their committee on motive-power presented a report recommending endless-rope haulage as the only practical plan for superseding animal traction. Though yet in its infancy, its advantages are, that it affords the means of furnishing ample power for maintaining speed up steep gradients, and for surmounting such obstructions as arise from snow; that the power does not depend upon adhesion between wheels and rails; that extra cars can be put on as required to meet larger traffic; and that economy can be effected in duller times. On the other hand, it is at present available under the most favourable circumstances only; the outlay is so great that a very large traffic is required for proving remunerative; the route must be comparatively straight, in default hitherto of any economical and simple plan for working round curves; and there are minor defects, such as always occur in novel mechanical enterprises. Owing to the low price of steel, the cost of constructing the tramway itself is less serious than that of maintaining auxiliary ropes; and is considered likely to be greatly reduced.

In connection with the prevalent employment of animal traction, the adoption of any car-starter, or mechanical contrivance for absorbing the momentum of the car in stopping and for giving it out again in starting, is represented by the report to be superfluous, on the ground that the excess of effort which has momentarily to be exerted for starting a car tells far less seriously upon the teams than does the continuous hammering of their feet along the hard road while the car is well in motion.

A. B.

The Flow of Water through Pipes.

By Hamilton Smith, Jun.

(Transactions of the American Society of Civil Engineers, vol. xii., 1883, p. 119.)

The results of eighty-eight experiments are given, chiefly made by the Author, partly selected from other sources. The pipes were 4 feet to $\frac{1}{2}$ inch in diameter, with velocities varying from 20 feet to $\frac{1}{8}$ foot per second.

Experiments 1–15 were made on three sheet-iron riveted pipes, laid side by side. The pipes had been coated with tar when laid five or six years previously, and their surfaces were quite smooth. The pipes were put together stove-pipe fashion, the joints being slightly conical. The greatest variation of diameter was $\frac{1}{4}$ inch. Experiment 17 was on a double-riveted sheet-iron pipe, $\frac{3}{8}$ inch thick at a point where the pressure was 887 feet of head. Round stones, weighing 25 lbs., passed through this pipe at 9 feet per second. Experiments 35 to 87 were made by the Author at New Almaden on small pipes of wrought iron, wood, and glass. No. 88 was on a new inverted siphon of double-riveted sheet iron, with a pressure of 800 feet at the lowest point. A block of wood, loaded to a density of 1·05, passed through this pipe at 20·9 feet per second, though the mean velocity was only 20·13 feet.

From these experiments the Author has deduced the coefficient m in the formula,

$$v = m\left(\frac{d}{l}h\right)^{\frac{1}{2}},$$

where v = velocity in feet per second; d = diameter, and l = length of pipe; h = effective head after deducting from the total head the loss at the mouthpiece of the pipe. The following Table gives an abstract of the results, omitting those on small pipes. The dimensions are in English feet.

No. of Experiment.	Material.	Length.	Diameter.	Effective Head.	Velocity per Second.	m.	——
1	Sheet iron, riveted, coated with tar, five to six years in use.	685	0·911	22·65	10·05	57·90	H. Smith.
2		697	0·911	17·83	8·69	56·89	„
3		714	0·911	12·10	6·95	55·95	„
4		721	0·911	9·62	6·12	55·49	„
5		731	0·911	6·20	4·76	54·06	„
6		685	1·056	22·71	10·76	57·47	„
7		700	1·056	15·52	8·68	56·71	„
8		709	1·056	10·13	6·98	56·86	„
9		718	1·056	4·80	4·61	54·91	„
10		684	1·230	22·04	12·30	61·82	„
11		696	1·230	17·13	10·75	61·76	„
12		705	1·230	11·59	8·52	59·89	„
13		711	1·230	8·71	7·33	59·72	„
14		712	1·230	7·81	6·86	59·07	„
15		720	1·230	3·61	4·40	55·99	„
16	Cast iron	5,280	4·0	5·0	3·46	56·22	Gale.
17	Sheet „	12,798	2·43 (?)	150·0	10·78	63·88	Spring Valley Company.
18	„	1,194	2·154	19·60	12·61	67·03	H. Smith.
19	„	29,580	1·333	420·0	6·82	49·54	Inst. C.E., 1855.
20	„	25,765	1·333	230·0	5·25	48·14	„
21	„	3,815	1·333	180·7	14·51	57·72	„
29	Cast and wrought	50,776	3·0	27·0	2·03	65·03	Rochester, W. W.
30		51,495	2·0	116·7	4·57		
31	Cast iron (incrusted)	11,217	3·0	20·22	3·0	40·8	Kirkwood.
32	„	29,715	1·67	30·26	1·49	36·22	„
33	„	44,400	1·25	226·0	3·46	43·4	Inst. C.E.
34	„	6,600	1·0	34·3	3·57	49·5	„
88	Sheet iron	4,439	1·416	296·1	20·13	65·56	H. Smith.

W. C. U.

The Water-Supply of Weissenfels. By G. Henoch.

(Deutsche Bauzeitung, 1883, p. 337.)

Until the present time Weissenfels has been dependent on a number of wells for its supply of water, and the water is largely charged with lime and polluted by organic matter; but it has now decided to have a supply of pure, wholesome water, not only in sufficient quantities to meet all ordinary industrial requirements; but under such pressure or head as will make it available in the upper storeys of houses, and for extinguishing fires.

South of the town, and between the villages Muttlau and Wiedebach, is a seam of lignite (Braunkohle) lying under thick boulder or drift-deposits. This coal is worked by means of a shaft from the Constantine mine, but as the seam is only separated from the water-bearing formation of red sandstone (Buntsandstein) below by a thin stratum of clay, the shaft gets flooded immediately unless the pumps are kept continually at work. An abundant supply of water being thus evidently available, it is proposed to drive through the red sandstone a gallery or adit a little over ¾ mile long, 6 feet high and 4 feet wide, which, starting above the village of Muttlau, 1¼ mile distant from the nearest part of the town of Weissenfels, will have its mouth 464 feet and its head 466 feet above datum, the town itself being about 318 feet only above the same level. This gallery or conduit will be bricked and faced throughout, and will form a reservoir capable of containing 2600 cubic yards of water.

The high level of this reservoir will, on the one hand, give a head of 148 feet for the town supply, and on the other will take off the water at a depth of 20 feet below the bottom of the shaft, thus excluding any chance of injury to the source of supply: moreover, the agreement between the town authorities and the owners of the Constantine mine guarantees the former against injury from the mine-workings.

An analysis of the water gives its composition as follows:

Solid residue after evaporation . .	30·0 parts
Organic matter	0·30 „
Nitric acid	nil
Chlorine	trace
Sulphuric acid	10·30 „
Lime	8·98 „
Magnesia	3·24 „

with 13·49 degrees of hardness before boiling, and 0·71 degree permanent hardness. The project provides for a daily supply of 660,000 gallons, or 33 gallons per head of population, whilst the yield, as judged by the work of the mine-pumps is at least 1,100,000 gallons per diem.

In consideration of the great advantages which this method of water-supply will confer on the owners of the Constantine coal-mine, since the pumping hitherto necessary will be entirely dispensed with, they have contracted to construct the conduit or reservoir, including all necessary temporary framing, but exclusive of brickwork, for the moderate sum of £2250, or at the rate of about £1 12*s.* 6*d.* per lineal yard.

W. H. E.

The Removing, bodily, of a Cartridge-Magazine at Romorantin Barracks. By A. de Rochas.

(La Nature, 20th October, 1883.)

A cartridge-magazine at Romorantin barracks having been condemned to destruction, on account of its position interfering with the general alignment of the barracks, the opportunity was taken to experiment by trying to move it bodily, taking merely such precautions as appeared necessary to attain success, but without employing any elaborate contrivances to ensure for the building immunity from injury. The magazine was square in plan, 11 feet on the side, and with walls of the same height, surmounted by a pyramidal roof, of which the apex was 23 feet from the ground. The walls were 15½ inches thick, and the total weight of the building was about 50 (metric) tons. Being built of inferior materials, a crack had early declared itself above the door, to neutralise which an iron band had been carried around the walls below the cornice. It was desired, in an experiment which might turn out unsuccessfully, not to exceed the probable expense of demolition. This entailed the employment of such materials only as could be found on the spot and used without cost. Such improvised plant consisted of some double-headed rails in 20-feet lengths, 15 cannon-balls 4·7 inches in diameter, and various timbers of different scantlings obtained from a neighbouring building in course of demolition. The mode of operation decided upon was simply to timber up the base and sides of the building, and haul it to the desired site by the aid of the cannon-balls and rails. By dynamometer-experiments under various conditions, the author had ascertained: firstly, that the power necessary to propel in this way a weight W was equal to $\frac{1}{80}$ of W; secondly, that the average force exerted by a man pulling steadily without jerk was about 88 lbs. It therefore required to move the building an effort equal to that exerted by sixteen men harnessed direct to it. The operation of raising the magazine on to the ways was the most difficult part of the work, and was indeed pronounced by some experts impossible, on account of the weakness of the masonry. This was, however, successfully accomplished, the foundation being bared at the same time that the cohesion of the walls was ensured by binding them together with two tiers of beams, one at the bottom and one at mid height, with morticed and tenoned joints secured by keys. Next, holes were cut at the ground-level, in two opposite walls, through which were passed, in the direction it was intended to move the building, two oaken beams; below these beams, and at right angles to them, four cross timbers were similarly inserted, and underneath the cross timbers, at each end of the building, were slid two rails on their sides with seven cannon-balls resting in the channel between the rail-heads. The upper rails on each side had been used as guard-rails for crossings, and were placed with the bent ends pointing upwards, so as to form a bird-mouth, and thus facilitate the entry of the cannon-balls. The building now rested partly on the carriage and partly on its foundations, it remained therefore to cut through the walls at the bottom in order to have it wholly supported by the cannon-balls. This was done for half the thickness of the walls from within the building, and finished from the outside. These operations were carried out by the contractor with great care and intelligence, insomuch that there was not a single hitch. Beginning at midday on Thursday, the 10th of May, the work of supporting the building on its temporary ways was completed on the following Saturday evening, twelve men being employed (three carpenters, four masons, and five labourers).

A hawser was now passed around the four walls, and the pull of sixteen men sufficed to set the building steadily and smoothly in motion towards its new site, the first journey being to the end of the first length of rail-path. New foundations were then prepared 105 feet distant, in a position where the magazine could again be utilized. The moving of the building was completed by means of a capstan, two men sufficing to haul, while two others helped behind with levers, and four superintended the manœuvring of the cannon-balls. It took altogether three hours and a half to pass over the 105 feet, but had the ways been made smoother, by the adoption of longitudinal sleepers, and continuous for the whole distance, so as to have dispensed with fleeting the rails, a much higher rate of speed could have been attained.

The Author gives some particulars of other achievements in moving bodily heavy weights, from one of which he conceived the idea of the operation above described.

F. G. D.

Influence of the Porosity of Walls on the Salubrity of Houses.

By Professor E. Trélat.

(Quatrième Congrès International d'Hygiène et de Démographie, September 1882.)[1]

That walls are porous, and traversable by gas and air, there are the results of many observations to prove. Mr. Hudelo experimented with walls of brick and of rough millstone, from 4½ inches to 18 inches in thickness, under pressures of 0·08 inch to 1·69 inch of water. Mr. Somasco also experimented on small cylinders of various materials, under pressures varying from 0·039 inch to 1·18 inch of water. The conclusions drawn from these two sets of experiments were identical, and are summarised by M. Trélat as follows:—First, that the quantities of air passing through walls or materials are sensibly proportional to the initial pressures, and that the passage of air through permeable materials is modified in a small degree only by the thickness traversed. For instance, through lias stone of thickness proportionally as 1, 5, 25, the quantities of air passed are as 4, 2, 1, whence, it appears, that the thickness of walls may be considerably increased without reducing considerably the volume of air passed through. Secondly, that under pressures varying from 0·039 inch to 1·18 inch of water a wall of soft stone 20 inches thick—the minimum thickness of the walls of stone-built houses—passes from 68 cubic inches to

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[1] The original is in the library of the Inst. C.E.

1,978 cubic inches of air per square foot per hour. Thirdly, that when the material is moistened, the quantity of air traversed is reduced by from 50 to 60 per cent. Fourthly, cements are permeable in a very small degree. Dry plaster is rendered impermeable by two coats of oil paint. Marbles, and wood across the grain, are impermeable to pressures not exceeding 1·18 inch of water.

The Author discusses the bearing of the foregoing experimental data on the salubrity of houses. Taking a room of ordinary dimensions, he finds that the change of air effected by transmission through the walls does not amount to one-twentieth of the capacity of the room per hour—a quantity without sensible influence on ventilation. He attaches importance, on the contrary, to the reflex absorption of miasmatic emanations by the walls, by which the purification of the room is promoted. Miasma thus absorbed, he argues, meet with the air which advances from without, and becomes oxygenated. He refers, in support of this conclusion, to the houses built in countries which are rich in soft stones:—the basin of the Garonne, for instance, where porous limestone abounds, and on the Loire of Touraine, where porous tufa prevails. There, are seen clean walls, healthful rooms, and pleasant-looking neighbourhoods. But, in the country of granite, gneiss, schists, and even freestone, which are impermeable to gases, are found, on the contrary, unbecoming interiors, filthy walls, and rooms filled with offensive odours.

The Author concludes that as people have to spend their existence within permeable walls, and as the transfusion of external air can only take place through external walls, he must look with disfavour upon partition-walls, which are inaccessible to pure air. In hospitals, barracks, and schools, he would remove interior divisions, abandon double walls, and condemn super-position of storeys. He would banish impermeable stucco and plaster, and envelop the interior life by enclosures bathed by the external air.

D. K. C.

The Warming and Ventilation of Schools, Dwellings, &c.[1]

By E. DENY, Ingénieur-Directeur de l'usine de Mertzwiller.

The Author enters very fully into the cause of the vitiated air produced in dwellings, and notes that a considerable difference exists between the various authorities on this question, as to the exact amount of air required to ensure proper ventilation; but considers that a mean supply of fresh air equal to 500 cubic feet per hour is amply sufficient for adults varying from 20 to 60 years of age.

The volume of air required for ventilation having been determined, the next point considered is how this air is to be supplied

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[1] The original is in the library of the Inst. C.E.

and extracted from the space ventilated, and the Author justly remarks that good ventilation is not ensured by simply providing inlets and outlets at haphazard; but that it is desirable to extract the vitiated air near the points generated, and if all sources of vitiation of air, except that produced by the inmates of a room, were excluded, the extraction should be at the points it is most likely to accumulate.

Considering the physical properties of the air in connection with warming, the Author remarks that, in any room in which the general temperature of 20° Centigrade is maintained, if a portion of the air that was previously at this temperature and its density equal to 1·209 kilo. per cubic metre, be cooled down by being brought into contact with surfaces such as glass windows and cool walls having a temperature of 0° Centigrade, its density would then be 1·298 kilo., and each cubic metre would have a downward movement capable of communicating a velocity equal to 0·725 metre per second, or practically the air would travel in 3 min. 3 secs. over a wall space 12 feet high.

With regard to the question of the loss of heat in contact with cooling surfaces, the Author remarks that this loss from contact with air is independent of the nature of the wall-surfaces, but depends on the difference of temperature between these surfaces and the external air, and on the form and extent of the external walls, and the velocity of the wind acting upon them.

Different methods of warming are then considered, and the Author, in speaking of direct radiation, says the air rarely attains on this principle a high temperature, and the caloric rays are nearly all absorbed by the glass windows and cold wall-surfaces, causing ascending currents along the walls with opposite movements in the interior of the apartments. This effect is that which is generally produced in ordinary rooms warmed with open fires.

When warmed air is used as a medium for heating any space it rises to the top of the room, and, in cooling, establishes along the walls descending currents of warm air, thus heating them, and the space can thus be maintained at an even and constant temperature.

The Author therefore thinks that, in all applications of heating, the production of descending currents of the air in the space warmed is desirable, and consequently any system of warming by radiation, producing upward currents of air against the walls or glass surfaces, is to be avoided if an even temperature is required.

He considers that the maximum effect of any heating and ventilating arrangement will be produced when the stratum of warm air has reached the floor line; at the same time these descending currents should dilute the vitiated air, so that it also reaches the lower stratum, and be thus removed, through apertures formed along the whole side of the refrigerating or external wall.

To ensure this the difference of temperature between the external air and the extraction shafts should not be less than from

25° to 27° Centigrade, and the area of outlets calculated on an assumed velocity of exit of 1·0 foot to 1·6 foot per second.

In referring to the points for the introduction of the warm or fresh air, the Author maintains that all inlets formed in the external or refrigerating walls or under windows, should be avoided, and also that air introduced at a level at which respiration takes place, must be on a wrong principle, as at that point it would meet the vitiated air.

After reviewing various other means, he concludes that as an even distribution of the air at a level below respiration is a *sine quâ non* of good ventilation, in order to realise this, all heating of the fresh air above the normal temperature of the space should be avoided.

In mentioning the best means to be adopted for warming and ventilating buildings, in order to carry out the views expressed in this Paper, the Author condemns the use of open fires or direct radiation; but advocates the construction of an air-chamber below ground, warmed by a hydrocaloric stove, in which the heat is generated by the direct action of the fuel, or by steam or hot water.

The power of this apparatus is to be calculated for warming the air for ventilation only. The air from this chamber is to be diffused over the several spaces to be ventilated at a level below respiration. With this, and fixed in the space itself to be warmed, should be another hydrocaloric stove heated as before-mentioned, the surfaces of which are calculated to maintain, independent of ventilation air, the required temperature in the rooms.

These hydrocaloric stoves must, however, be encased in sheet-iron, leaving an air-space around them, and thus reduce to a minimum any radiation from them to the refrigerating walls, as these, as well as the room, must be maintained at the required temperature by circulating the air of the apartment itself through the encased space.

The air thus drawn into the stoves must be distributed at a level below that of respiration, and diffused at a level above that point.

In some buildings, this arrangement cannot be carried out, and modifications more or less inconvenient have to be resorted to, and in some cases, for a single-storey building, the two stoves may be united, by constructing from the air-chamber three air-shafts, one drawing the air from the space to be warmed and delivering it into the lower part of the same, the second shaft conveying this air, warmed to the required degree, back to the apartment, and the third shaft utilized for ventilation air only.

For buildings of more than one storey, the Author advocates, in conjunction with the hydrocaloric stoves, mixing or distributing chambers, in order that in all cases the air supplied for warming may be different in temperature to that for ventilation, the latter must never be diffused from the mixing-chamber above the normal temperature of the spaces to be ventilated.

The Author prefers heating the hydrocaloric stoves by the direct power of the fuel, in preference to using steam or hot water, and he explains in a diagram the details of a stove which meets all the requirements enumerated in this Paper.

A chapter is also devoted to the consideration of gills attached to heating stoves and pipes, in which some valuable researches and experiments are described, concluding with the remark that the addition of gill-plates does not diminish the main temperature of direct-heating surfaces, and no appreciable difference of temperature can be found between the ends of the gills and the solid parts of the envelope; but they have the advantage of producing in a very small space, a much more powerful effect, combined with a lower temperature of heating surface for the air to pass over.

W. W. P.

[Note. The Author's data will not be generally accepted by English sanitarians. In the first place the cubical space allowed will be thought too low; secondly, stove-heated air unless duly moistened and purified is not considered acceptable; and thirdly, the modes of admission of fresh air and extraction of vitiated air will be disapproved.—W. W. P.]

Heating by Means of Ribbed Steam-Pipes. By E. Deny.

(Bulletin de la Société Industrielle de Mulhouse, Sept.-Oct. 1883, p. 575.)

Two drying-rooms at the works of Messrs. Blech Brothers, at Saint-Marie-aux-Mines, are heated by means of ribbed steam-pipes of cast-iron; that is to say, pipes cast with external circular flanges, and in close succession, for the purpose of increasing the radiating surface. The drying-room on the ground floor is about 26¼ feet by 23½ feet, and 11 feet high, having about 6,750 cubic feet of capacity. The drying-room on the first floor is of nearly the same dimensions as that on the ground floor, and has 6,855 cubic feet of capacity. Each room is heated by steam of 2½ atmospheres, circulating in ten cast-iron ribbed pipes, 6·56 feet long, joined up with four plain bends to form a serpentine of five straight limbs 13 feet 1¼ inch long, and 2 feet apart, with a low inclination, so that condensation-water may flow off. The pipes are 4¾ inches in diameter internally, and 0·43 inch thick, making 5·6 inches of external diameter. The ribs are 11 inches in diameter, and extend, therefore, 2·7 inches from the surface of the pipe; they are 0·35 inch thick at the base, tapering radially to 0·16 inch at the edge, and are placed apart at 1·38 inch of pitch. The total superficies of one of these pipes is 58·5 square feet, of which 50·75 square feet is exhibited by the ribs. For ten pipes, the area is 585 square feet; including the four bends, 603 square feet. If the pipes had been plain, the total surface would have amounted to only 114 feet, which is multiplied 5·3 times by the addition of the ribs.

From the results of six-hour tests, it appears that, whilst the external temperature was 66° Fahrenheit, the temperature of the heated air discharged was 90½° Fahrenheit, and that of the condensation-water from the pipes was 158° Fahrenheit. After the apparatus had got into steady working order, 1,111 lbs. of steam was condensed per hour, for 113° Fahrenheit difference of temperature between the steam and the air of the chamber, corresponding to 0·98 lb. of steam condensed in each room per hour per degree Fahrenheit of difference of temperature, equivalent to (0·98 ÷ 603 =) 0·00169 lb. per square foot. Comparing these results with those deduced by Mr. Peclet from the action of plain pipes, it appears that the condensing performance of the ribbed pipes is 4½ times as much as that of plain pipes of equal diameter and length would have been.

The advantages claimed for the ribbed pipes are, that a given heating power is attained by a much less length of pipe than is necessary in employing plain pipes; that the ribbed pipes are much more durable than wrought-iron pipes, which are much thinner; and that the first cost, and the cost for maintenance, are less.

D. K. C.

Behaviour of Mineral Wool around Steam-Pipes.

(Transactions of the American Society of Civil Engineers, vol. xii., 1883, p. 253.)

Professor Egleston, in a Paper on this subject,[1] communicates additional details of his investigations of the action of slag-wool on steam-pipes. His analyses show that sulphur is contained in all slag-wools, eight samples of which contained from 1·10 per cent. to 3·07 per cent. of sulphur, the chief elements in quantity being silica, about 38 per cent.; alumina, about 9 per cent.; and lime about 45 per cent. That the sulphur is set free, in the presence of moisture, and does act on the material of the pipe, is proved by the analysis of the scale removed from the pipes at the places where they gave way, which could be easily detached by the nail in pieces of considerable size. On analysis the scale exhibited the following composition:—lime, 3·09 per cent.; magnesia, 1·07 per cent.; protoxide of iron, 3·98 per cent.; sesquioxide of iron, 81·51 per cent.; silica, 2·46 per cent.; water, 4·38 per cent.; sulphuric acid, 3·75 per cent. This analysis shows the presence of a considerable quantity of sulphuric acid still remaining in the scale, although it had been exposed for some time to the air and moisture before it was submitted for examination. Under such conditions the iron would generally be precipitated as sesquioxide, while the sulphuric acid would be liberated and dissolved out.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxiv., p. 349.

A given weight of slag-wool was heated to a temperature below that of dull red in a tube, and a current of dry hot air was rapidly passed through the tube for some time. No sulphur was separated, and none was given off; showing that the wool was safe so long as it was kept dry. Slag transformed into wool does not differ in any respect from slag in the lump, except that it becomes a mass of interwoven fibre, retaining a large quantity of air, the non-conductor. When the wool is compressed, it has very little more value than the slag in its original form.

D. K. C.

Coverings for Steam-pipes. By Professor J. M. ORDWAY.

(Fourteenth Report of Boston Manufacturers' Mutual Fire Insurance Company, 1883.)

In the course of his investigations the Author had first to decide upon the methods to be adopted for determining the efficiency of the various non-conductors to be tested. Of the two modes employed heretofore, the air-chamber method, based upon the temperature of the air in a close box containing a portion of the covered pipe to be examined; and the condensation method, which depends upon the amount of water formed in a section of the covered pipe under trial, in a given number of minutes, both are more or less imperfect. In the first of these methods, it is difficult to fit a box of any kind so closely to the covering that there will be no circulation of air into, and out of, the enclosed space, and a lack of tightness is fatal to the accuracy of the experiments. Again, a box surrounding the pipe and covering presents a large radiating and cooling surface, as compared with the covering itself, and there is no ready way of determining the amount of this continual radiation, which increases with the temperature of the air within the chamber. Further, assuming all outward radiation from the box could be prevented, the internal air would in time acquire the temperature of the steam in the pipe, and all coverings would give the same result; the only way to obtain useful observations would, in this case, be to start with everything cold, and to note the time required to raise the air in the chamber to a given temperature, but this would be hardly practicable. This plan obviously only gives results which are comparative, and not such as are absolute or quantitative. The Author describes, by reference to diagrams, the apparatus he employed to test various coverings by this method.

The second, or condensation method, is indirect, and also a little uncertain, because it necessarily assumes that the pipe is all the time filled with dry steam, which can scarcely be the case; all that can be expected is a mixture of real steam with more or less mist. And if this mist, which has lost its latent heat, is reckoned as invisible steam, the figures will not give the exact truth. In arranging the length of pipe under trial, the cap and other fittings give rise to further minute errors, which cannot easily be reckoned. The Author explains the apparatus he employed for trials by condensation, and he also describes a modified form of testing he has devised, by combining the condensation-method with a calorimetric method, to obviate the difficulty caused by the mist. By this latter mode of testing, of which diagrams are given, he obtained an absolute measure of all the heat transmitted to water by the covering. Each covering tested was tried by each of the three methods described, and an average of numerous tests of each is given.

Pipe-coverings may be divided into four general classes:—

1. Those consisting essentially of light fibrous matters, as hair, slag-wool, or paper, applied immediately to the pipe.
2. Those composed of a paste or mortars, which is plastered directly on to the pipe, in one or several coats.
3. Those having an air space next the pipe.
4. Complex combinations of different layers.

In all, forty-six sets of trials were made of different coatings, of which the most efficient was found to be simple hair felt, with a cheap cover of burlap. As the general result of the tests, it was ascertained that while a naked 2-inch pipe, carrying 60 lbs. steam, may condense 181 grams per foot per hour, the amount of condensation may, by a cheap covering, be reduced to 46·5 grams, making a saving of 134·5 grams per hour, or 1·345 kilograms, = 2·96 lbs. of steam in a day of ten hours. The Author shows that this saving, on a length of 100 feet of steam-pipe, would approximately represent an annual economy of 5 tons of coal, on a total of three thousand working hours.

The average result of the forty-six coverings, the trials of which are set forth in a Table, is that 24·623 kilogram-centigrade heat-units are transmitted, in each hour, by each foot in length of the pipe-covering. The average weight of the different coverings tested was 49 oz., or a little over 3 lbs. per lineal foot.

The Author deduces from his experiments the following conclusions:—

The best coverings are those which consist chiefly of light fibrous, or porous substances, such as hair felt, slag-wool, charcoal, rice-chaff, and diatomaceous silica, or "fossil-meal."

Those which consist of a paste or mortar, that is, plastered on, are inferior, with the exception of specially prepared "fossil-meal."

The complicated coverings are not so far superior as to warrant their necessarily increased cost.

The fibrous or spongy matter, employed to form a covering, should be at least an inch thick.

Hair felt should not be applied to the pipe, either directly, or with the simple intervention of a thin wrapping of asbestos paper. A moderate air-space prevents scorching of the felt, and gives the best results, and such an air-space can most economically be enclosed by a thin sheet of straw-board, kept off the pipe by plaster-rings. The hair felt should have an outer wrapping of cloth.

Silicated charcoal, a material suggested by the Author for the purpose, is cheap, and appears to form a satisfactory coating.

Slag-wool is incombustible, and a poor conductor of heat, but entails certain difficulties in its application.[1]

Rice-chaff, moistened with water-glass at 33° B., and sewn up in a cloth wrapper, affords a cheap and effective covering.

G. R. R.

Daussin's Domestic Steam-Engine.

(Bulletin de la Société d'Encouragement pour l'Industrie National, vol. x., 1883, p. 500.)

Mr. Daussin, of Fives-Lille, is the inventor of a small steam-engine and boiler which, by means of a fire not greater than that of an ordinary domestic stove, may be employed to drive one or two sewing-machines or other small tools.

The boiler simply consists of a hollow plate about 18 inches in diameter, which serves at the same time as the cover for the stove and the bed-plate of the engine. Below this plate are a number of narrow pendant tubes, about 5 inches in length, offering considerable heating surface. Above it is attached a pipe or column, from the top of which the steam is supplied, while the sides of the pipe carry the bearings for the shaft. The arrangement of the latter, as well as of the cylinder and valves, is almost identical with that of the toy vertical oscillating engines commonly seen in the windows of an optician's shop. The supply of feed-water is maintained by having a raised tank, from which a certain quantity of water finds its way by gravitation to the lower part of the above pipe, each time a special valve is opened. This latter valve is a circular one, and is opened and shut by the revolution of a toothed wheel driven from the main shaft.

The motor has received a prize from the Industrial Society, and is recommended by the Committee as cheap and handy, and "offering guarantees of good working and safety." The last point is secured by the small dimensions of the boiler, which has a capacity of only 3 litres, and a heating-surface of 25 square decimetres, and also by only loading the safety-valve to 8 lbs. on the square inch.

H. S. H. S.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxiv., p. 349.

Welter's Drying-Machine. By — Lévy.

(Bulletin de la Société Industrielle de Mulhouse, Sept.-Oct. 1883, p. 555.)

Mr. E. Welter's drying-machine for drying piece-goods is at work in the establishment of Messrs. J. Heilmann & Co., Mulhausen. It is a continuous hot-air drying machine, on the selvage-pincer system (*rame à pinces*), having two endless chains travelling horizontally. A dressing- or sizing-machine is placed at the head of the drying-machine, and a folding-machine is placed at the other end to receive and collect the dried cloth. The drying-chamber contains two horizontal ranges of cast-iron pipes heated by steam, one above the other, of which the lower range contains thirty-six pipes, and the upper range forty-two pipes. The pipes are cast with flanges or ribs on their exterior for the purpose of augmenting radiating surface. They are connected at the ends two and two, making a serpentine course for the steam. The cloth is passed over a copper cylinder, also heated by steam, at the exit from the chamber, designed to dry the selvages which have been held by the pincers. The condensed steam is taken off by means of steam-traps. The chamber is formed of wood, and is made with a door at each end. Dry air enters by passages under the chamber, and is heated by the steam-pipes to a sufficiently high temperature, amounting to 175° Fahrenheit. The moist air is drawn off by ventilating chimneys. Both the supply and the discharge of air are regulated by means of valves and dampers. The cloth on entering the chamber passes freely below, and returns above the lower range of pipes, for a length of 66 feet, before it is engaged by the pincers; and after being liberated from the pincers it traverses the chamber to and fro at the upper part, making together a free traverse of 132 feet, out of a total traverse of 165 feet in the chamber.

The length of the pincer range is 33 feet between centres of pulleys, and the total length of the machine is 46 feet; its height is 8¼ feet, and its width is 10¾ feet. There are eighty pipes, having 881 square feet of radiating surface. The feeding-drum has an area of 19 square feet, heating by contact, making together 900 square feet of surface. There are two entrances for dry air, respectively 12 inches square and 10 inches square; and there are eight outflows, 12 inches square, for saturated air, at the upper part, four at each side, and three at the level of the ground.

This machine was tested in June, 1882, for the purpose of determining the quantity of steam necessary for evaporating 1 lb. of water. The steam thus consumed was ascertained by measuring the condensation-water discharged by traps from the steam-pipe. To determine the weight of water evaporated in the machine, these weights were noted, namely:—the weight of the dry pieces before being sized, the weight of sizing liquid used, and the weight of the dried pieces. The sum of the first and second weights, minus the third weight, was the quantity of water evaporated. The quantity of steam condensed amounted to 2,905 lbs., making, with an addition of 5 per cent. for unavoidable loss, 3,050 lbs. of condensed steam. The pressure of steam on entering the chamber was 4¼ atmospheres. The quantity of size used amounted to 1,081 lbs., of which 997 lbs. as water was evaporated, showing that 3·06 lbs. of steam was condensed per pound of water evaporated. Forty pieces of linen cloth (*cretonnes*) were sized and dried in the course of the test. The testing was maintained for about eight hours, and the length of time that each piece was exposed to the drying heat varied from six minutes to nineteen minutes. The length of pieces dried amounted to 4,337 yards. The temperature within the drying-chamber gradually rose from 82° to 121° Fahrenheit at the floor. In the upper part of the chamber the thermometer stood for most of the time at about 170° Fahrenheit.

D. K. C.

Seymour's Differential-Vernier Press.[1]

(American Machinist, vol. vi., 1883, p. 1.)

In presses used for stamping delicate work much trouble is often experienced in adjusting the dies to the exact throw required. The essential feature of the Seymour press is a differential vernier, by which the required regulation can be performed with great exactness.

The die is actuated in the usual manner by an eccentric, which actuates a sliding block that moves in a slot in the plunger. The hole in the sliding block is bushed to receive the eccentric, and this bush is itself eccentric, so that if it is turned round it alters the throw of the die.

The bush is secured from revolving by a set pin, which can be inserted in a differential series of holes ranged around the circumference of the bush and in the sliding-block; by this means the throw can be regulated to the one-thousandth part of an inch, which in some classes of work, such as stamping watch-cases, is found necessary.

The presses are well spoken of by those who have used them.

W. P.

Chilled Cast-Iron Turning-Tools.

(American Machinist, vol. vi., 1883, p. 7.)

A correspondent writes to the American "Machinist," and states that he has made and used chilled cast-iron turning-tools for turning drums, pulleys, and work of a similar character, and for

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[1] An illustrated account of this press will be found in "Engineering" for Oct. 19, 1883, p. 363.

such work they have been pronounced superior to the best steel tools.

The tools require to have rather more metal under the point than steel tools, and should be ground on the top only: when the chilled part is all ground away, they are melted up.

The writer has not used them for planing, and expresses doubt as to whether they would stand the jar, but for lathe work they are good and cheap.

W. P.

On the Lubrication of Heavy Bearings.

By Professor J. M. Ordway.

(**Fourteenth Report of Boston Manufacturers Mutual Fire Insurance Company, 1883.**)

The Author refers to the results obtained with an oil-testing machine, devised by Mr. J. H. Woodbury,[1] to be used under heavy pressure, either at high or low speeds, which was similar to one previously constructed, mainly from his own design, for experiments with the lubrication of light bearings, run at high speeds. In the former set of tests it had been shown that, when running at high speeds, the best and safest results were obtained with pure mineral oil, commonly called "paraffin oil," bearing a fire-test of not less than 300° Fahrenheit, subject to an evaporation not exceeding 5 per cent., at a heat of 140°, in twelve hours, and as fluid as possible consistently with the oil remaining in the place where it is needed. In both of the machines the method of applying water, within the substance of the metal disks of which the frictional surfaces consist, was successfully made use of. The tests, in the case of heavy bearings, of grease *versus* oil, fully confirmed the deductions from actual practice in mills, and the Author has been led to the conclusion that greased bearings run at a heat of 110° to 180° Fahrenheit, and oiled bearings at 30° to 40° less. It does not follow from this that, taking the relative prices, only, of oil and grease, the latter may not be the cheaper; but grease cannot do its work until it is melted into an oil by the heat of the bearing, and this way of procuring an oil may be not only dangerous, but it is also very costly. Or, looking at the matter as a question of power, it may be put thus:—The power required for converting the work of the engine into heat, by friction of the journals, is a very expensive way of melting grease, and requires about twenty times as much coal as heating over a fire.

G. R. R.

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[1] Minutes of Proceedings Inst. C.E., vol. lxv., p. 428.

Distribution of the Heat from a Blow of the Steam-Hammer.

By H. Tresca, Hon. M. Inst. C.E.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, p. 222.)

Rectangular bars of various metals were placed on the anvil, and subjected to one blow of a hammer of a given weight, falling from a given height. In order to bring into evidence the exact lines in which the heat developed by the blow was generated, the sides of the bar were polished, and received a thin coating of wax. A single blow of the hammer sufficed to melt the wax in a particular zone or belt, traceable on each side of the bar, indicating the portion of the lateral faces which had been raised during the blow to the melting point of the wax. The figure of the zone suggests generally the letter X; two ogee lines intersecting each other at the centre of the bar, or what may be called the neutral axis. Mr. Tresca compares the figure thus formed to the space comprised between the two branches of an equilateral hyperbola. In other words, it resembles an egg-glass.

Assuming that the development of heat exhibited externally, takes place throughout the width of the bar, Mr. Tresca calculates the quantity of heat developed thus evidenced, and its mechanical equivalent, which he finds to amount to upwards of 80 per cent. of the work of the blow, measured by the product of the weight of the hammer by the weight of the fall, in the case of iron bars; and to upwards of 70 per cent. for bars of copper. The difference of these quantities is due, no doubt, to the greater conducting power of copper, whereby a larger proportion of heat escapes unproved by the melting of the wax in copper, than in iron.

The lines of development of heat figured by the melted wax, are in fact those in which the displacement of the material takes place under the blow.

D. K. C.

The Indicator as a Detector of Lost Motion. By R. Grimshaw.

(Journal of the Franklin Institute, October 1883, p. 245.)

Mr. G. W. Brown, of Boston, had occasion to remedy a pronounced case of pounding in a high-speed steam-engine, in which the cause of the pounding or thumping eluded every endeavour to detect it. He therefore devised a self-recording means of detecting the time and the position, in the course of the stroke, when the thump took place, by forming a special connection with an indicator, in nowise connected with the indicator-piston, nor influenced by the steam-pressure. There was added to a Crosby-Brown indicator a special multiplying lever, having vertical movement only, and having a pencil which made a trace underneath and parallel to the atmospheric and the vacuum lines of the ordinary indicator-diagram.

The lever is of the third order, having the fulcrum at one end, and a point of connection with the thumping member at an intermediate point, whilst the pencil is at the other end. The intermediate connection is formed by a pin acting vertically on the lever, with a spring to take up the slack. The pin is connected by a line of wire to a multiplying lever, adapted to take up and transmit the loose movement of the main shaft. Should there be any such movement horizontally, it would cause horizontal vibration of the free end of the lever bearing against it, and would tighten or slacken the cord, and produce a vertical movement of the lost-motion lever on the indicator. A corresponding upward or downward indication of the pencil, relatively to the straight line representing the path of the crosshead or the piston, would indicate the point at which the lost-motion commences, where it ends, and its direction.

By the aid of this rig the inventor effectually cured a sometime incorrigible engine.

D. K. C.

Transmission of Power by Belts, Cords, and Wire Ropes.

By GEORGES LELOUTRE.[1]

A former abstract[2] of a paper by the Author upon this subject gave a summary of his researches; and these have since been detailed in the present extensive essay, to which was awarded in 1881 a gold medal offered to competition.

Having found that so-called practical formulas and rules are seldom of much value, in consequence of being made too general, the Author twenty years ago began experiments of his own, which he has recently extended and rendered more complete. In his two first chapters he examines the facts relating to the stretching, elasticity, breaking, and slipping of cords and belts. Most of these facts run counter to the notions generally entertained. Above all, the influence of *time* on the elongation and breaking-strain of belts, cords, and webbing, cannot be neglected.

The experiments on the elongation, elasticity, and breaking-strength of belts were all made with dead weights, as described in the former abstract, so as to avoid the error arising from friction in testing by any lever machine. Detailed particulars are given of thirty experiments, the results of which are analysed. The elastic stretching of leather belts under tension is by no means proportional to the strain: the amount of stretch increases much less rapidly than the strain, or, in other words, the modulus of elasticity

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[1] "Les Transmissions par Courroies, Cordes, et Câbles métalliques." Paris. 1884. 346 pages, 5 plates. The original is in the library of the Institution.

[2] Minutes of Proceedings Inst. C.E., vol. lvi., pp. 376–380. Repetition of what has already been given in the former abstract is avoided here as far as possible, but not entirely.

rises with the strain. The resistance to stretching is greatest when the strain reaches about 850 lbs. per square inch of sectional area in leather belts; and in india-rubber and webbing at a rather lower strain. However rapid the stretching during the first hour, a considerable further elongation takes place when the strain is continued for two or three weeks; but two or three days' continuance is long enough to give a sufficiently accurate result for practical purposes.

In respect of elasticity, belts are never in practice at rest or relaxed long enough to recover wholly from their stretching. Even when at rest, a belt that remains on its pulleys continues to sustain throughout its length a strain equal to the mean between that on the driving and that on the trailing span when running. The elasticity of ordinary new leather is remarkable: a thong of very common leather, breaking at 2,280 lbs. per square inch, stretched as much as 22 per cent., of which it recovered at once rather less than half; and after fifteen months' rest it had returned to exactly its original length. There appears indeed to be no true permanent set for leather; it stretches to the same extent whether broken under a rapidly increasing load or under one applied for a long period, but in the former case it recovers more readily than in the latter.

The breaking strength for belts of all materials is from half as much again to twice as much when the load is increased up to the breaking strain in a few hours, as when that strain is slowly reached in the course of five or six months. In ordinarily good leather the breaking-strain when reached in an hour or two will be as high as 4,300 to 4,800 lbs. per square inch; but under loads slowly applied it will be only 2,850 lbs. and even less. India-rubber is rather weaker. Hence any results arrived at in trials that last only a few hours must be reduced in the above ratio for practical use. Though the strongest leather is not that which stretches least, yet in practice the mistake is generally made of looking for belts not to want tightening up too frequently, without regard to whether they are working at one-third or at one-sixth of their breaking strength. For a belt to last however, the latter consideration is the more important: the leather employed should be the strongest and most elastic; and frequent tightening may readily be obviated by the simple expedient of subjecting a fresh belt for some days before using it to a tension of from 1050 to 1,450 lbs. per square inch. Some belts are made of leather that has been compressed in thickness by calendering; but the leather recovers its original thickness, just as it does its shortness after stretching. The tension which the Author has been led to adopt for leather belts in practical working is from 640 to 780 lbs. per square inch, instead of the much lower strains generally recommended of only 200 to 350 lbs. The tensile strength does not appear to be impaired by repeated breakages. Hence the permanent load on belts may be made high, without fear of overstraining them or impairing their elasticity, their greatest strength being apparently developed under a tension of about 850 lbs. per square inch. Trying annealed iron wire, by way of analogy or contrast, the Author found its breaking strength unaffected by the time occupied in testing; the first fracture diminished its elasticity, when thoroughly annealed, but not its strength[1]; it undergoes sudden elongations after several days, to a greater or less extent according as the load is heavier or lighter; and lastly, under a load applied for a length of time, the stretch on breaking is about a third of what it is when the wire is broken in only about an hour's testing.

As to slipping, a very common mistake in practice is to suppose that the coefficient of friction, or ratio between the tensions of the driving and trailing spans of a cord or belt, increases with the size of cord or breadth of belt or diameter of pulley. But so long as the arc of contact on the pulley contains the same number of degrees, the size of cord, breadth of belt, and surface of contact, have absolutely no effect on the ratio between the two tensions at the moment when slipping is on the point of taking place. On this head the Author's experiments are conclusive, ranging as they do from sewing-thread up to hemp and cotton cords of 1¼ inch diameter, and from leather thongs only ⅜ inch wide up to belts 12 inches broad, with pulleys of from 8 inches to 8 feet diameter, on which the surface of contact varied in the ratio of 1 to 500, while the arc of contact ranged from half a turn (180°) up to 3½ turns. What does modify the coefficient of friction for belts is their greasiness, and especially the degree of polish of the pulley-rims on which they run.

Throughout the Author's experiments the coefficient of friction was found to be nearly constant: it ranges from 0·070 to 0·075 for new cords, and from 0·090 to 0·180 for new leather belts that have not run long enough to get saturated with swarf; for old belts covered with a layer of dirt the coefficient is much higher; and when the pulleys are imperfectly polished it may rise to 0·300 and upwards. The coefficients commonly assumed are at least twice as high as these. When the pulley-rims are rounded over slightly convex in transverse section, the friction is rather less than when they are flat; for pulleys above 6 or 7 feet diameter the difference is immaterial. For well-greased belts the coefficient of friction diminishes as the tension increases; but this is only because the grease gets partly squeezed out when the belt runs tighter over the pulleys. The experiments were made by keying a pulley fast on a fixed horizontal shaft, and hanging a belt over it with equal weights at each end, and then gradually increasing the load on one end till the belt slipped. The trial must be continued long enough, because a load insufficient to cause in a few seconds any perceptible slip will produce a con-

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[1] The Author's inference in the former abstract, that the strength (*nerf*) of metals was impaired by the first fracture, as well as their elasticity, is here seen to be corrected in respect of annealed iron wire.

siderable slip in the course of hours. On the other hand, as the steady experimental pulley is free from the jar that occurs in all running pulleys, the adhesion is higher upon it than in actual practice. Moreover at high speeds of from 2,000 to 6,000 feet per minute a belt draws air in between itself and the pulley-rim, whereby the adhesion is impaired; this can be obviated by slotting holes at intervals through the rim, parallel to its edges, and the belt will thereby be kept running straight on the pulley.

The particulars and results are given in detail of eight experiments with cotton cords, ten with hemp cords, twenty-one with leather belts, and one with an india-rubber belt. From these experiments the Author is led to adopt the following minimum values for the coefficient of friction, which give the corresponding ratios for the tensions of the driving and trailing spans when on the verge of slipping, the arc of contact with the pulley being 180° in each case. For new cotton or hemp cords, coefficient 0·075; ratio of tensions 1·27 to 1·00 for pulleys with flat rims, and 1·45 to 1·00 for pulleys with semicircular grooves or with V grooves having an angle of 80°, the nipping of the cord in the groove being neglected. For ordinary new leather belts, coefficient 0·155, ratio 1·67 to 1·00. For new india-rubber belts, and for well-greased old leather belts, coefficient 0·200, ratio of tensions 1·90 to 1·00. No account is taken of extra adhesion from the pulley-rims being imperfectly polished or merely turned, because in working they gradually become more and more polished by the stretching of the belt upon them under the load.

The practical examples, by which in his third chapter the Author illustrates the application of his results to actual belt gearing, comprise the transmission of 42, 80, 280, and 700 horse-power by leather belts, and of 60 horse-power by an india-rubber belt: with regard to each of which the whole of the particulars are fully detailed and analysed, including the description and strength of the belts, the loads on the bearings of the flywheel and pulley-shafts, the strength of the flywheel, the mode of joining the ends of the belt, and the relative advantages of cords and belts. Owing to the damaging effects of centrifugal force on lap-jointed belts, preference is given to butt-joints stitched with either one, two, or three thongs, through four rows of holes spaced zigzag, the stitching being so done as to range the thongs all parallel to the edges of the belt on its inner face, and diagonally on its outer; the thongs should be of very supple leather, such as the white *kronenleder* (crown-leather) obtained from Switzerland. Attention is drawn to the importance of flywheels being properly proportioned to the trains of toothed gearing they control, the flywheel being often made too heavy. The construction and strength of pulleys with curved arms is examined at much length. In regard to the relative friction with belts or cords and with toothed gearing, it is shown that theoretically the advantage is always more or less on the side of belts or cords; while a practical confirmation of this conclusion is furnished by the instance of a spinning mill, in which toothed gearing driving 18,000 spindles was replaced by belts, with a saving of 20 per cent. in friction or 3½ per cent. on the effective driving power transmitted; and in no case do belts practically cause more friction than toothed gearing. The particulars are furnished of three examples where driving by belts did not prove thoroughly successful; and the conditions are pointed out which led to the less satisfactory results.

The fourth and concluding chapter treats of the loss through friction and other dead resistances in transmitting power through great distances by means of wire ropes. This loss the Author considers can be brought down as low as 30 or even 20 per cent. in transmitting power by ropes through distances of 6 to 7 miles and upwards. While electric transmission may be employed in connection with great mountain waterfalls, water-power nearer at hand may be utilized advantageously through ropes. The heavy outlay in each case is the same, being that incurred in constructing the necessary leats, or head and tail races, and in erecting the hydraulic motors themselves. The coefficient of friction for an iron-wire rope in a round-bottomed pulley-groove that is lined with leather standing on end is found by the Author's experiments to be 0·220 for half a turn round the pulley. From experiments at a spinning mill at Oberursel, Nassau, to which water-power is transmitted through iron-wire ropes from a distance of 3,150 feet in eight spans of about 394 feet from pulley to pulley, it was found that, when using the maximum quantity of water, equivalent to 175 HP., the useful effect, tested by friction-brake at the mill, was not more than 99 HP., or only 56 per cent. The aggregate loss of power, through friction of pulley bearings, stiffness of ropes, and resistance of air, ranged between 11½ and 12 HP. for seven of the above spans together. The ropes were 0·59 inch diameter, and ran at about 55 to 60 miles an hour in ordinary working; the pulleys were 14·8 feet diameter, the weight of each with its cast-iron axle being about 28 cwts. From these experiments the Author deduces 0·090 as the coefficient of friction for the pulley-bearings, 0·092 as the coefficient of stiffness of the iron-wire ropes, and 0·000451 as the coefficient of air-resistance to the pulley-arms. These coefficients are discussed, and confirmation is obtained for them from a comparison with those hitherto accepted under different forms from recognised authorities upon the subject.

A. B.

The Transmission of Power at Grenoble. By — Boulanger.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, pp. 628–633.)

This is a report by the Author in the name of the Committee appointed by the town of Grenoble, to follow the experiments of Mr. Marcel Deprez, by whom the electrical transmission of power was effected. The machines employed were the same as used at the workshops of the Northern Railway of France, but the wire of the inductors of the receiver had been changed, and the insulation of the various parts improved. Both machines were insulated from the earth by battens of dry wood. The receiver was installed at Grenoble, and the generator at Vizille, a distance of 14 kilometres; they were connected by two silicious bronze wires of 2 millimetres diameter, having a resistance of 167 ohms. The two machines had the following resistances:—

$$\begin{array}{llr}
 & & \text{Ohms.} \\
\text{Generator} \left\{ \begin{array}{l} \text{Inductors} \quad . \quad . \quad . \quad . \\ \text{Rings} \quad . \quad 2 \times 18 \cdot 30 = \end{array} \right. & \left. \begin{array}{r} 20 \cdot 10 \\ 36 \cdot 60 \end{array} \right\} R = 56 \cdot 7 \text{ ohms.} \\
\text{Receiver} \left\{ \begin{array}{l} \text{Inductors} \quad . \quad . \quad . \\ \text{Rings} \quad . \quad . \quad . \quad . \end{array} \right. & \left. \begin{array}{r} 61 \cdot 00 \\ 36 \cdot 00 \end{array} \right\} r = 97 \cdot 00 \quad ,,
\end{array}$$

The results are given in two Tables; one shows that the maximum efficiency attained was 62 per cent. in transmitting nearly 7 HP.; and that the loss by the line was negligible. The ratio of efficiencies is calculated from mechanical measurements, and in this report no electrical data are recorded.

P. H.

On Traction by Accumulators. By EMILE REYNIER.

(L'Électricien, 1883, pp. 193–242.)

The Author commences with a description of the tramcar exploited by the French Electrical Power Storage Company in Paris, which was lent by the Compagnie Général des Omnibus de Paris for the purposes of the experiment.

The accumulators, eighty in number, and weighing each about 30 kilograms (66 lbs.), were placed under the seats, and connected in multiples of five to a commutator, whence the current was taken off to the motor, a Siemens D^2 with the necessary additions to allow of the reversal of the direction of rotation, so that from thirty to eighty cells could be used according to the power required at each moment. The driver had before him this commutator, the handle commanding the guide-wheels (the car being arranged to run both on the ordinary road and on rails), and the brake-lever; the ratio of the revolution of the dynamo to that of the wheels was 25 to 1.

The coefficient of traction on the level rails was about $\frac{1}{100}$, and ten seconds from starting the normal speed of 3 metres per second (6·7 miles per hour) was attained; the greatest incline was $\frac{11}{1000}$, on which the car could be started without difficulty.

The method adopted of connecting up the accumulators is however faulty, as the first part being always in circuit are run down to a far greater extent than the others, so that in recharging there is a considerable waste of energy. To obviate this the Author proposes to arrange the commutator so that the whole of the accumulators are always employed, but coupled in tension or quantity according to the requirements, and to use a separate set for exciting the magnets of the motor. Thus, taking the same number (eighty) of accumulators, he would use eight for the magnet circuit, and divide the seventy-two into four sets of eighteen each, capable of connection in either of the following ways:—

All 72 in series.
2 parallel of 36 „
4 parallel of 18 „

By merely reversing the current through the armature, the direction of rotation is changed; and in descending inclines the current generated by the motor could be used to partially recharge the accumulators, at the same time acting as an efficient brake.

The conclusions the Author draws from the actual experiment are that the motor is good, the accumulators passable, and the mechanical details fairly satisfactory, but capable of improvement in the future.

In comparing the cost of traction by accumulators with that effected by animal power, the Author has abstracted his data for the latter from the published accounts relating to the tramcars of the Compagnie Générale des Omnibus de Paris, and for the former has based his estimates on grounds which allow of profits to manufacturers, and royalties to inventors.

The work expended for one journey of 11·6 kilometres (7·2 miles), with a load of eighty passengers, is 4·05 HP.-hours, and eight journeys are made per day; the daily cost of animal traction per car is 65·04 francs (51*s.* 7*d.*).

As the weight of the accumulators and electrical apparatus considerably increases the weight of the car, the work in this case per journey is 6·29 HP.-hours, which at 40 per cent. effective, demands for the steam-engine charging the batteries 15¾ HP., hours, and at eight journeys per day the cost of this comes out as 39·66 francs (31*s.* 6*d.*) per day, allowing for annual depreciation 100 per cent. on the accumulators, 25 per cent. on the electrical apparatus, and 20 per cent. on the mechanical, and the car to stand idle fifteen days in the year. Two motors are supplied to each car to lessen delays from accident.

Traction by accumulators, therefore, shows an economy of 39 per cent. over that furnished by animal power, and there is no doubt that the difference will be still greater when this mode of traction has advanced beyond its experimental stage.

F. J.

Timber Guides in a Colliery-Shaft. By J. LAROMIGUIÈRE.

(Bulletin de la Société de l'Industrie Minérale, vol. xii., 1883, pp. 189–195.)

In the Faymoreau coalfield, Vendée, France, a vertical shaft of rectangular section, 8 feet by 5 feet clear, has been sunk through compact and generally very micaceous sandstone, to a present depth of 257 yards, which will hereafter be greatly exceeded. It is timbered throughout with oak sets or frames, of 7½ inches square scantling, having a crossbar in the middle, 4 by 7½ inches, which divides the shaft into two compartments; the frames are fixed about 2½ feet apart. The total cost of sinking and timbering was £2,673, or £10 8*s*. per yard. The four guides, all fixed in the long axis of the pit, are of oak, 4 by 5 inches, and in lengths of about 10 feet; their ends are notched and bolted together, and to strengthen the joint, which is 8 inches long, a 1½-inch cover-strip of oak is added at back. They are slightly notched upon the timbers of the frames, to which the two outside guides are secured by means of plate-ended bolts; the screwed shank of the bolt passes through the guide-bar, while a flat palm, continuous with the shank, rests on the top of the frame-bar, to which it is both nailed and bolted. The two inner guides are together bolted to the middle crossbar of the frame by a single bolt right through, with nut at each end; but the Author regrets he did not use here double palm-bolts, like those fixing the outside guides, as they would have been far more convenient for facilitating repairs of the guides. The plate-ended bolts afford the means of fixing the guides very firm, in spite of the small space available for getting any fastening in; the pit-frames are also saved thereby from any damage which they might otherwise sustain in consequence of their having themselves to carry the guides. The fixing of the guides from bottom to top of the pit was done in twenty-four days of twelve hours each, or at the rate of about 11 yards per day; it cost £122 or 9*s*. 6*d*. per yard. Hence the whole cost of sinking, timbering, and fixing the guides came to altogether about £10 17*s*. 6*d*. per yard.

A. B.

Shaft-Sinking through Quicksands.[1] By G. Köhler.

(Berg- und Hüttenmännische Zeitung, 1883, pp. 447, 448.)

The Author describes a process invented by Mr. Poetsch, which consists in freezing the water in those parts through which the shaft is to pass, and in excavating the frozen mass by ordinary means. In this way, the difficulty in dealing with the water and the running sand is avoided, and the work of sinking is carried on in firm and dry ground. In carrying out the system, the shaft is sunk to the water-bearing stratum of a larger diameter than is ultimately required. Small bore-holes, about 3 feet apart, are put down in a circle just outside the perimeter drawn to the true radius of the shaft, that is, in the sides of the shaft as it will be when excavated to its required diameter. A second circle of bore-holes inside the first, and consequently in the ground to be exca-

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[1] Since this Abstract was in type an illustrated description of this system has appeared in "The Engineer" for 30 Nov. 1883.—Sec. Inst. C.E.

vated, is next put down, and a single hole in the centre completes the set. As far as the character of the ground will permit, these holes are bored simultaneously by means of the sand-pump. Over the bore-holes is fixed a tubular ring out of which pass small copper tubes, provided with cocks, to the bottom of the bore-holes. At bank, is a Carré freezing-machine, which produces a high degree of cold by means of the ammonia process. Heat is abstracted from a concentrated solution of chloride of magnesium and chloride of calcium, the freezing-point of which is between −35° and −40° Centigrade. This solution, at a temperature of about −25° Centigrade, is driven by a small force-pump into the annular tube before mentioned, whence it is distributed among the small copper tubes reaching down the bore-holes. After passing down these tubes, the solution ascends in the lining-tubes of the bore-holes, and, through the medium of a common ascension-pipe, is conducted back to the machine. In this way, a constant circulation is kept up. It will be seen, that while ascending in the bore-holes, this cold solution abstracts heat rapidly from the water in contact with the outside of the lining-tubes, and that the greatest action takes place at the bottom. This gives a gradually increasing mass of ice from the top to the bottom of the bed, a circumstance happily in accordance with the increasing pressure of the water. The time during which the freezing process has to be carried on is, according to Mr. Poetsch, from ten to fourteen days, under normal conditions, that is, when the outer ring of holes can be placed in the position already indicated.

When the ground has been sufficiently frozen—to be ascertained by boring—the work of sinking commences. This consists merely in excavating the solid ice, and in building up the brick or iron lining (walling or tubbing) of the shaft. As the sides of the shaft are firmly frozen to a depth of 2 or 3 feet, there can be no inflow of water, and consequently the sinking presents no difficulty. For greater security, the circulation of the freezing-liquid is kept up in the outer circle until the shaft has been carried down completely through the watery stratum.

At the sinking visited by the Author, which has furnished the first practical test of the system, the method unfortunately could not be carried out under the best conditions. For in this case, the sinking was not commenced from the surface, but from the bottom of an existing shaft 100 feet deep. This shaft is rectangular, 10 feet 4 inches broad and 14 feet 6 inches long. The thickness of the quicksand bed is 13 feet. All the bore-holes in this case, 23 in number, have necessarily been placed inside the shaft, where they are greatly in the way of the workmen. The freezing was completely effected by the 10th of August of the present year, and the ice proved to be remarkably hard and strong. The work would have been finished ere this had not the managers of the mine required evidence of the extent of the freezing to be obtained in several ways before they would allow the sinking to be commenced. This evidence showed that the compact ice extended 3 feet from the bore-holes. Though this circumstance has prevented a perfect example of the system from being exhibited, yet enough has been accomplished to place the practicability of the system beyond doubt.

As this first application has not been made under normal conditions, it is not yet possible to compare the cost with that of the ordinary methods. But it is evident that the advantages and economy of the Poetsch system stand in direct relation with the quantity of water in the quicksand bed. When the quantity is small, the ordinary methods suffice. But the difficulties increase so rapidly with the flowing character of the sand that the cost becomes very great, sometimes ruinously great, so that the work is rendered impracticable. In such cases, Poetsch's system offers such advantages that it will probably be often adopted, especially as it affords a much higher degree of safety in working.

G. G. A.

Improvements in Deep Earth-Boring. By OLAF TERP.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1883, p. 450.)

The system of deep earth-boring by means of the diamond crown-borer fails in soft, and especially in gravelly, strata. It is well known that a thin bed of this nature very seriously retards the progress of a boring; and it is this defect which has hindered the general adoption of the diamond-borer for prospecting purposes, for which it is in other respects so admirably suitable, on account of the solid core which it brings up. To obviate this the Author has invented a steel-borer of a peculiar construction, which is substituted for the diamond crown when a soft stratum is met with. In conjunction with this boring tool, hydraulic pressure is made use of to force up to the surface, as mud, the material cut away at the bottom of the bore-hole. This constitutes the principal feature in Terp's system, and hence the latter has been named "the hydraulic quick-boring system." The removal of the sludge by this means not only keeps the drill-edge clear, but saves the great loss of time which would otherwise be incurred by the frequent raising and lowering of the tools. When the soft stratum has been pierced, and solid rock again reached, the diamond crown is replaced, and cores several inches in diameter, and from 15 to 20 feet long, are brought up. The system has been employed, with highly satisfactory results, at the collieries of Joh. D. Stark, at Prague.

G. G. A.

Rock-boring with Jalorimek's Hand Machine-Drill.

By JOSEF HOZÁK.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1883, pp. 382, 435.)

The Author gives an account of his experience with Jalorimek's improved rock-drill. This drill, which is of the non-percussive class, and is provided with steel cutting teeth instead of the usual carbonate "diamonds," was described in an earlier number of the same publication, and the results of its behaviour in practice has been awaited with some interest. The machine was set regularly to work by the Author in April of the present year, and his account of its performance extends to the middle of July. The rock through which the gallery was driven was granite, at first of a moderate degree of hardness; but later its hardness increased considerably. In this rock, the rate of boring with the machine in question was, on an average, half an inch a minute, the diameter of the bore-hole being 2 inches. This rate was reduced in the hard rock to about $\frac{3}{8}$ of an inch a minute. The boring-tool made 5 revolutions a minute, the proportion between this and the winch-handle turned by the men being 1 to 9. The drill was set to advance $\frac{1}{10}$ of an inch at each revolution. Only one man was employed at a time at the winch-handle, to which, in the moderately hard rock, he gave a speed of 45 turns a minute. This speed was kept up for 10 minutes, when his place was taken by another. These two worked alternately 10 minutes at a time. At first the boring-tool lasted till a depth of about 32 inches had been reached; but in the harder granite it had to be changed at every 2 feet. The labour of re-forming the teeth does not appear to be very great. It was found to conduce both to rapidity of progress and to a saving of explosives to employ the machine-drill to bore the centre holes required to unkey the face of the heading, and then to blast down the rock by means of hand-bored holes of half the diameter and half the depth. This combined system is strongly recommended by the Author. The central machine-bored holes were 4 or 5 in number, according to circumstances, and of a depth varying from 30 to 40 inches. Of the hand-bored holes, from 8 to 10 were required, of a depth varying from 12 to 20 inches. The time occupied in boring with the machine and by hand was as 2 to 1; and the number of holes needed, as 1 to 2. The central machine-bored holes were each charged with 1 lb. of blasting-gelatine, and these charges were fired simultaneously by electricity. The Author calls attention to the greatly increased effect obtained by the simultaneous ignition of these first shots, the rock being in all cases broken out to a depth of 32 inches and upwards. The hand-bored holes were charged with a cheap dynamite, and fired singly, with safety-fuze. The Author concludes from the results obtained that, as compared with hand-boring, this combined system, with Jalorimek's machine-drill, affords very considerable advantages both in speed and in economy.

G. G. A.

Failure of Iron Shaft-Tubbing at the Bâneux Colliery, Belgium.

By P. Banneux.

(Annales des Travaux Publics de Belgique, vol. xxxix., 1882, pp. 331–345.)

The rupture of the cast-iron tubbing of a shaft at the Bâneux colliery, in the province of Liége, in Belgium, claims the earnest attention of mining engineers. The accident is striking, both from its novelty and from the fact that none of the universally-adopted elements of security were absent. A committee of eminent engineers had designed the work, the quality of the materials and workmanship was beyond question, and the directorate had even increased the dimensions recommended by the engineers.

The tubbing of the Bâneux shaft was required to resist the pressure of 42 metres (138 feet) head of water. It extended from the thill of a coal-seam up to a height of 44 metres, the distance to surface being 60·5 metres; and it was composed in height of seventy-two sections of 0·60 metre each. This length of tubbing of 44 metres was divided into three equal portions, in which the thickness of the metal differed. In the lower portion this thickness was 34 millimetres (1·33 inch); in the middle portion it was designed to be 26 millimetres, and in the upper portion 19 millimetres. But during the execution of the work these portions were increased to 30 and 26 millimetres respectively. The shaft was not circular, but four-sided, the sides being unequal and curved, a form common on the Continent. In this shaft one segment was made to span the whole distance on each side. The segments on two opposite sides were curved to a radius of 3·85 metres (12·63 feet), giving a chord of 2·5 metres, and a versed sine of only 0·22 metre. On the other two opposite sides the segments were curved to a radius of 3·50 metres, giving a chord of 2·60 metres, and a versed sine of 0·27 metre. The segments were bolted together at the angles in the usual manner, the joints being made with strips of lead 3 millimetres (0·118 inch) thick. On the inside of each segment were three strengthening ribs, each 85 millimetres (3·34 inches) deep. It is customary to calculate the thickness of such tubbing on the assumption that the shaft is circular, and of a diameter corresponding to the curvature of the segments. Calculated on this basis, the thickness of the lower tubbing should have been, for the larger diameter, 32·34, say 33 millimetres, and for the smaller diameter 29·4, say 30 millimetres. The thickness actually given was 34 millimetres in both cases. Thus the dimensions adopted were not only arrived at in the manner sanctioned by experience and in conformity with the common practice, but, as an additional security, these dimensions were slightly exceeded. Thus nothing was wanting to give confidence in the solidity of the structure. Yet this tubbing, calculated, as it was supposed, with a wide margin for safety, to resist a head of water of 42 metres, gave way when the head had reached only 35 metres. The rupture occurred in the middle of the segments, and extended from the bottom to a height of 18 metres through thirty-one successive segments.

The purpose of the Author of this report is to show that tubbing of this character is not subjected solely to a stress of compression, as in the case of circular shafts; and that consequently the calculations which are based on that assumption are erroneous and dangerously misleading. He demonstrates that such segments are exposed to a transverse strain by the extremities being forced outwards against the pressure which holds the centre in position; that is, the force which is brought to bear upon those pieces tends to cause flexure, and the strain thus set up increases with the radius of curvature. Such a strain tends to break the segment in the middle, in the manner in which the rupture occurred at Bâneux. A careful measurement of some of the deformed segments showed that the versed sine had been diminished by from 1 to 2 centimetres, while their chords had been increased by from 2 to 4 centimetres. The Author recommends the adoption of a greater thickness of iron in these cases, and suggests the necessity of taking precautions to counteract the tendency of the angles to yield under the action of the external pressure. In the new tubbing designed for the Bâneux shaft these suggestions have been acted upon, and the structure is probably the most massive that has yet been constructed.

G. G. A.

Endless-Chain Mineral Railway. By ACHILLE BRULL, Paris.

(Bulletin de la Société de l'Industrie Minérale, vol. xii., 1883, pp. 165–180.)

This line has been constructed in the Department of Constantine, Algeria, for sending down iron ore from the mine of Aïn-Sedma, discovered in 1873 at the head of Alfensou Valley, to a shipping jetty in Tamanar Cove at the mouth of the same valley, this being the third cove westwards from the port of Collo. The mine is 2,300 feet above the sea, and its distance from the jetty across very hilly country is 3·728 miles as the crow flies. The railway deviates so little from this straight line that its actual length to the outer extremity of the jetty is 4·910 miles.

The line is worked automatically on the endless-chain system, the chain itself riding on the tops of the wagons, and engaging the upturned prongs of a fork on the end of each. In plan, the route selected is made up of twelve lengths, each as nearly straight as possible, and connected by curves of 20 feet radius. In profile, the line follows the ups and downs of the hilly route pretty closely; there are eleven tunnels, of 1,130 yards aggregate length, and of 6½ by 6½ feet section; and nine timber bridges of 6½ feet width on masonry piers, their spans amounting altogether to 420 yards. For convenience and economy of working, the line is divided into six self-acting sections, each worked by its own independent chain; the longest section is exactly 1 mile, and comprises three straight lengths of the line, as does also each of two other sections, while the three remaining sections each coincide with a single straight length. Every section begins and ends on a summit, excepting only that the lower end of the terminal section is on the jetty. At the upper end of each section a flanged drum, with steel rungs or teeth bolted to its rim, is carried on a vertical shaft, on which is fixed a brake-wheel; the speed is also controlled by a fly-governor driven from the drum-shaft. The chain takes ½ or 1½ or 2½ turns round the drum, according as the tension on the tighter side is not more than 1·1 times that on the slacker, or not more than 1·5 times, or more than 1·5 times. The chains are ¾ inch, ⅞ inch, and 1 inch thick, with links of ordinary shape, not elongated; the two larger sizes weigh respectively 19·8 and 23·5 lbs. per yard. The heaviest strain under which any chain works is 2·67 tons per square inch, or less than one-seventh of its breaking strength.

The ruling gradient on the line is 30 per cent., or 1 in 3⅓. The crests of the undulations along the profile are rounded off with circular arcs of such radius that the slacker chain hanging between successive wagons shall never touch the ground. Similarly the bottoms of the depressions are rounded out with such catenary curves that the tighter side of the endless chain shall never lift out of the forks on the wagons.

The railway is laid throughout with a double line of 20·7 inches gauge; the loaded trucks descending by one line draw up the empties on the other. Bessemer rails of Vignoles section are used, weighing 18·1 lbs. per yard; the joints are fished with a couple of bolts, and carried in Bessemer chairs, on transverse sleepers of native fir pickled with sulphate of iron. The trucks are of native timber, each weighing 3·14 cwt. empty, and carrying 8·84 cwt. of ore; the wheels and axles are of steel, the wheels being 8 inches in diameter. The whole weight of materials that had to be carried up country amounted to 470 tons, of which 45 tons were for the brake-stations; the chains came to 135 tons, the rails 175, and the sleepers 115 tons. The rails were carried by mules, while pieces too big for mules had to be carried by men. The cost of constructing the line was £21,500, exclusive of general expenses, which amounted to about a quarter as much.

After six weeks spent in overcoming the numerous difficulties encountered in getting the several sections of the line to work in the proper self-acting way, beginning with the highest section and following downwards to the sea, the whole length was successfully opened in July 1880, with a delivery at first of only 25 tons a day. Within three months, everything having been got into regular working order, the delivery had reached 400 tons of ore per day of ten hours, at a cost of 7*d.* per ton, exclusive of redemption of plant; the cost would be lower still, if the output from the mine were larger. Altogether forty men are employed: there are two at each of the six brake-stations, and one at each of eight intermediate points.

Investigating the power to be absorbed by the brake-wheel at the head of any section of the line, the Author shows that it is independent of the undulations in the hilly profile of the section; and that, multiplying the difference of level in feet between the two ends of the section by the net load of ore per foot run of line, the power is the excess of this product over the product resulting from multiplying the gross load of full and empty trucks per foot of double line, both by the horizontal distance in feet between the two ends of the section, measured along the route of the line, and also by the coefficient of friction. The working strain which the endless chain has to stand is proportional, firstly to the load of the full trucks per foot run of line, secondly to the horizontal length of the section worked by the chain, and thirdly to the difference between the tangent of the mean gradient of the section and the coefficient of friction. The average result over the whole of the six sections in regular working is found to be that the coefficient of resistance to motion is 0·025 of the weight in motion in the case of the full trucks, and 0·030 for the empties, or respectively 56 and 67 lbs. per ton.

A. B.

On Driving Stone Headings without Explosives.

By Emile Laguesse.

(Annales des Travaux Publics de Belgique, vol. xxxix., 1882, pp. 458, 459.)

In driving a stone drift at the "Bois de Boissu" colliery, in the Mons district, Belgium, the strata was found to be so charged with fire-damp that it became impossible to continue the use of explosives. Recourse was therefore necessarily had to other means of carrying on the driving. The system adopted has shown itself to be adequate to the circumstances of this case, and is worthy of mention as a successful solution of a somewhat difficult problem. The rock was a very hard grit, lying in horizontal beds. A machine drill, of the Dubois and François type, was employed on the face of the heading in the following manner. Across the middle of the face a row of holes were bored, from 3 to 4 inches in diameter, and 3 feet deep, the distance of the holes apart being from 5 to 6 inches. When all these holes had been bored, a special tool was substituted for the drills, having a rectangular striking surface, 6 inches long by 2 inches wide, and provided with teeth like a saw. By means of this tool the rock left between the holes was cut through, leaving a horizontal groove, varying in width from 2 inches to 6 inches, and of a depth of 3 feet, extending across the face of the heading. This groove was intended to serve the same purpose as the "holing" or undercutting in coal. Other holes, of smaller diameter, were then bored above and below the groove, and in greater or less proximity to it, according to the strength of the rock. Conical iron wedges of slow taper, placed in these holes and driven in by the machine-drill, provided with a hammer for the purpose, broke down the rock between the holes and the groove. These operations were continued until the whole face had been brought down, when an advance had been made of about 2 feet 8 inches. This advance varied with the nature of the ground, and still more with the skill of the workmen, who did not attain to the average length of 2 feet 8 inches till after they had acquired considerable experience in this system of working. The shifts, which were of eight hours, consisted of three men, one in charge of the drill, and two labourers. The driller worked eighteen consecutive hours. The average rate of progress made under these conditions was 8 feet 2½ inches a week, the section of the heading being 6 feet 11 inches by 7 feet 2½ inches. When the special difficulties of this driving are taken into account, this rate of progress must be considered satisfactory.

G. G. A.

The Iron-Ore Deposits of the Province of Minas-Geraës, Brazil.

By A. DE BOVET.

(Annales des Mines, vol. iii., 1883, pp. 85–122.)

The high and mountainous region which forms the centre of the province of Minas is peculiarly rich in mineral deposits. Its diamond-fields have long been known as among the most productive in the world, and they are vigorously worked, though the primitive method of extraction is still followed, and the unsystematic conduct of the operations do not lead to the greatest profit obtainable from this source of wealth. The auriferous deposits are both rich and extensive, and these might be made to yield gold in paying quantities under an economical system of working. Some of the richest and most easily accessible of these deposits are in the hands of English companies, chief among which is that of the Saint John Del Rey mines. Lead-ore, rich in silver, also exist, in several places, and graphite and plumbago of good quality have been discovered. But less generally known is the fact that enormous deposits of iron-ore exist in the district, under conditions that render their working easy and profitable. It is mainly for the purpose of directing the attention of European engineers and capitalists to this promising field for enterprise that the Author has collected and made known the facts brought together in this Paper.

The iron-ores of the province of Minas are remarkable for their extraordinary abundance, their richness, and their purity. They are to be found almost everywhere in the centre of the province; sometimes in outcrops of enormous extent, often worked into to a great depth by the gold miners in search of the precious metal; sometimes deposited in large masses in the bed and upon the banks of rivers, the floods of which carry them away and scatter them over other localities. In many places they constitute the track of the roads, the dust of which sparkles so brilliantly during certain hours of the day that the eye can scarcely bear to look upon it. So abundant is this ore, and so ready to hand, that large quantities of it are used as building stone; this is notably the case in the town of Ouro-Preto. All of these ores belong to the category of oligist iron. Arenaceous oligist iron-ore, mixed with a few grains of quartz, and forming a very friable rock, is still worked for gold. A micaceous oligist iron-ore, also mixed with quartz in fine grains, and forming a friable rock; a specular iron-ore, sometimes found in magnificent crystals; and compact oligist iron-ore of very fine grain, and forming an extremely hard and tenacious rock, are other forms of this mineral. The fracture of the latter, where the gangue does not exist, is like that of a bar of steel, except that the colour is somewhat darker. There is also a conglomerate covering, in a generally thin bed, a large extent of country at the foot of the oligist iron deposits. This rock is locally known as "canga"; it is clearly formed at the expense of the other deposits, portions of the several rocks of oligist iron, bound together by a red hematite cement, being easily recognisable in it. This rock is, as a consequence of its mode of formation, full of cavities. Being firm and strong, of the same composition, and sensibly of the same richness as the ores whence they were derived, but porous, it seems to constitute an altogether exceptional ore, lending itself completely to the requirements of metallurgy. All these ores are remarkably pure; they are without a trace of phosphorus or sulphur. The only gangue appears to be quartz, but this does not exceed 5 or 6 per cent., except in the "canga," in which it may be in a little larger proportion. Manganese is always found in these ores, often only as a trace, but sometimes in considerable quantity, as much as 9 per cent. in some samples. These remarkable ores, equal, if not superior, to the best ores of Sweden, Algeria, and the Pyrenees, may be had for the labour of picking them up. In some places they crop out from the hill-sides, as at Pitanguy, for example, where, thanks to the labour of the gold-miners, the outcrop of a bed 450 to 600 feet thick may be seen at one view, over an extent of several miles. In other places, covering an immense extent of country, occurs the "canga," a superficial deposit, the thickness of which is often as great as 25 or 30 feet. Everywhere the streams carry down and deposit pulverulent oligist iron, ready washed for whoever will take the trouble to collect it. Mr. Gorceix estimates the mass of deposits at the foot of the Serra De Caraca at 8,000,000,000 tons. But without such estimates, whoever has travelled through these regions must necessarily have come away with the impression that the deposits are practically inexhaustible.

Unfortunately for this country, so rich in metallic ores, no coal exists in the neighbourhood of these deposits. Lignite, of good quality, is found in several places, and in beds of workable thickness. But this has only a future interest when the industry shall have been sufficiently developed to use the fuel in the gaseous form. But there is an abundance of wood, and wood charcoal must be the fuel employed in the reduction of these iron-ores. The extensive forests of the province of Minas are capable of supplying fuel on a large scale for many years to come, without the material rising much in value. Hence it will be possible to carry on metallurgical operations for a long time very cheaply by means of wood fuel. It may be added that water-power is abundant, and easily utilizable, in this mountainous country. At present the means of transport are insufficient; but a railway will shortly be completed up to the boundary of this mineral district, and commercial enterprise only is needed to continue it into the heart of that region.

G. G. A.

The Value and Use of Blast-Furnace Gases for the Production of High Temperatures. By JOSEF v. EHRENWERTH.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1883, pp. 537–539.)

If the gases of blast-furnaces be compared with those of the regenerative furnace, the former are found distinguished from the latter in only two essential particulars; first, the notably smaller proportion of nitrogen, which is from 54 to 57 instead of from 64 to 66 per cent.; and second, the large proportion of carbonic acid as compared with the carbonic oxide present. The ratio $\frac{CO_2}{CO}$, which in good regenerator gases is usually below 0·3, is in blast-furnace gases often as high as 1·0, and only in altogether exceptional cases does it fall as low as 0·4. Both of these distinguishing qualities may be easily accounted for. The first is due to the fact that oxygen is liberated in the reduction of the iron, and the second to the fact that the reduction of the ore is largely effected through the means of carbonic oxide, whereby the CO is burned to CO_2. While the former of these distinctive differences raises the quality of the gases as fuel, the latter diminishes it in a notable degree. They stand as follows:—

	Heating Power of 1 Kilogram.	Theoretical Temperature of Combustion, C.°
Blast-furnace gases	688 cal.	1,660
Average regenerator-gases from coal . .	920 „	1,820
Best regenerator-gases from charcoal . .	878 „	1,967

This low heating value and the considerable variations to which it is subject are the reasons why blast-furnace gases are used only for those processes in which a very high temperature is not required, as the roasting of ore, heating the blast, and the generation of steam. For the highest temperatures, such as are required in iron-furnaces, they are useless on account of the high ratio of $\frac{CO_2}{CO}$. The Author considers it to be quite practicable to reduce the carbonic acid to carbonic oxide, and so to regenerate the gases in the true sense of the word. To effect this, nothing more is needed than to pass the blast-furnace gases through a sufficiently thick layer of red-hot coal. If carried out under favourable conditions the consumption of coke or good coal would be from 17 to 20 kilograms per 100 kilograms of gases of 20·60 CO_2 and 24·23 CO. Assuming, as it is only fair to do, that the regeneration is not complete, and that there exists a ratio $\frac{CO_2}{CO} = 0 \cdot 24$, the result is gases of the following composition:—

	Weight.	Volume.
CO	34·87	35·1
CO_2	8·37	5·3
CH_4	0·28	0·5
H	0·18	2·5
N	56·30	56·6

Giving 937 cal. per kilogram of gases and 5,563 cal. per kilogram of carbon, with a theoretical temperature of combustion 1940°. These gases are superior in heating effect to any regenerator gases yet employed, being equal to the best coal-gas in its ratio of $\frac{CO_2}{CO}$. They are applicable to all uses in iron mills where the highest temperatures are required. A very great advantage would be derived from their use in the Siemens-Martin process.

The Author asserts that though the principle of improving gases by regeneration is not new, yet its application to the gases of blast-furnaces in order to make them serve for the production of very high temperatures has not, so far as his knowledge extends, been either carried out or proposed. He further states that he has prepared a pamphlet in which he has entered into the question more in detail and illustrated by drawings a regenerator of the kind here alluded to. To this pamphlet, published in Leipsic, he refers the reader for further information.

G. G. A.

On the Burning of Iron and Steel.

By Prof. LEDEBUR.

(Jahrbuch für den Berg- und Hüttenmann, 1883, p. 19.)

Iron that has been raised to near its temperature of fusion and slowly cooled is designated as " burned " or overheated metal. It is both red-short and cold-short, and exhibits a coarse, crystalline structure, and a bright glistening fracture. Such iron contains oxygen. But this oxygen is not, as is commonly believed, derived from without during the heating; but it was previously contained in the iron itself through the medium of the scoria or slag-impurities mixed with it. When the iron is raised to the fusing heat, or near it, a chemical reaction takes place; the metallic iron reduces the sesquioxide to protoxide, which, by being dissolved in the iron, alters the properties of the latter. The coarsely crystalline quality of iron so treated is not due to the presence of the oxygen. The metal usually contains a notable quantity of phosphorus, which is well-known to give a coarse grain accompanied by the quality described as cold-short. The crystallization takes place during the slow cooling while at rest. The greater the proportion of phosphorus present, the lower is the temperature to which the iron may be raised without being burned. Pure iron should not take up more than 0·25 per cent. of oxygen in solution. Though this substance does not greatly affect the ductility of the metal when cold, it acts like sulphur on its malleability.

The qualities of steel also undergo change when heated to a high temperature, or when subjected to a lower temperature for too long a time. The richer the steel is in carbon, the lower is the temperature at which the change takes place. Therefore, the harder the steel, the more carefully is it to be dealt with in the fire. Such overheated steel becomes coarse-grained and brittle; that is, cold-short. If the temperature be increased, showers of sparks are thrown off, and the steel is said to be " burned." The alteration brought about in this way has generally been attributed to a diminution in the proportion of the carbon constituent, though this assumption is not warranted by the results of analysis. The presence of manganese and silicon is of more weighty consequence. When steel containing these is heated, it is not the carbon, but the manganese and the silicon that first become oxidized, and there results an important change in the properties of the steel. Later, the carbon is oxidized; and while the oxide of carbon escapes, those of the manganese and silicon remain behind, and the whole molecular structure of the metal is altered. If the heating be carried still farther, the iron will next be oxidized. A cast-iron furnace door, exposed for several years to the flame of a coal-fire was found to contain 27·8 per cent. of oxygen, in combination with iron, sulphur, nickel, copper, phosphorus, and arsenic. The cause of the sparks is not the combustion of the carbon, and the consequent generation of carbonic oxide gas, but the escape of gases imprisoned in the steel. Similar results may be brought about by exposing the steel to a lower temperature for a longer time; the oxidation of the constituents will, in this case, be effected in the order mentioned above, the only difference being in the slower action. Steel altered in this way is well described as "dead." A regeneration of the metal by mechanical treatment is hardly possible, since the original chemical composition cannot be restored by such means.

G. G. A.

On the Determination of Temperatures in Gas-Retort Furnaces.

By E. Leclerc.

(Compte-rendu de la Société technique de l'Industrie du Gaz en France, 1883.)

It is important in gasworks to pay particular attention to the retort furnaces, and for this purpose frequently to measure the temperatures of the retorts, flues, and chimneys. The use of pyrometers for this purpose is not always satisfactory, and Mr. Leclerc gives the following details of the plan adopted at the works of the Paris Gas Company for the determination of such temperatures.

The apparatus consists of a circular wooden vessel, held together with iron hoops, to contain 10 litres (17·6 pints) of water when filled up to a level where there are three holes in the sides. This vessel is provided with a movable cover, having a circular opening in the centre, and a kind of wooden basket or sieve extending nearly to the bottom of the vessel. On the upper face of the cover a small handle and a rising ledge are fixed, and a hole is made for inserting a thermometer. A cubical block of iron is also provided, weighing 2 kilograms, and an iron rod, with handle, for inserting into a hole in the iron block. To use the apparatus the rod is inserted into the hole in the iron block, and the latter is placed in the position where it is required to determine the temperature. If for a retort, it should be placed in the centre, the rod withdrawn, and the retort-lid put on. If in a flue, the block should be placed on a brick, and the sight-hole closed; or, if in a chimney, an opening must be formed, through which the block is inserted, and allowed to remain suspended on the bar. The bucket is placed on a stand or level surface, and filled with water until it flows out of the three holes in the sides, which are then plugged, the cover put on, and the thermometer inserted in its place, with the stem projecting 3 or 4 inches above the cover. The cover is then rotated five or six times by means of the handle, and an observation taken of the temperature. The bucket is then placed in front of the retort, or place where the temperature has to be taken, and at a convenient distance therefrom. After exposure for twenty-five minutes in the retort or flue, the block of iron is removed by inserting the iron rod into the hole, the rod is rested on the rising ledge of the cover, and sharply withdrawn with the block, which, when it comes in contact with the ledge, becomes detached and falls into the water. The cover is then rotated eight or ten times, and the indication of the thermometer again noted.

The following rule for calculating the temperature of the iron is given:—

t Initial temperature of the water;
t_1 Final „ „ „
P Weight of water = 10 kilograms;
p „ iron = 2 „
c Specific heat of iron = 0·126;
T Temperature of retort or flue;

$$T = P\left(\frac{t_1 - t_0}{p\,c}\right) + t_1;$$

which, with the weight given, becomes $T = 39{\cdot}68\,(t_1 - t_0) + t_1$.

If the result of an experiment gives

$$t_0 = 11^\circ \qquad t_1 = 42^\circ$$

the temperature would be $31^\circ \times 39{\cdot}68 + 42^\circ = 1{,}272^\circ$, the calculation being for the temperatures on the Centigrade scale.

C. G.

The Electromotive Force of Alloys.

By J. TROWBRIDGE and E. K. STEVENS.

(Proceedings of the American Academy of Arts and Sciences, 1882–1883, p. 221.)

The Authors record the results of a series of experiments to determine the variation in the electromotive force of an element, of which one pole was formed by an alloy of tin and lead, or zinc and copper, when the proportion of the constituent metals was varied. The other pole of the element consisted of a platinum strip, and the liquid employed was water, or dilute sulphuric acid formed by the addition of one-tenth of a cubic centimetre of water to about one hundred and fifty cubic centimetres of distilled water.

ALLOYS of LEAD and TIN.

Percentage of Lead.	Percentage of Tin.	Electromotive Force in Volts.	
		With Water.	With Dilute Sulphuric Acid.
100	0	0·238	0·661
90	10	0·240	0·689
80	20	0·222	0·696
70	30	0·201	0·708
60	40	0·258	0·704
50	50	0·224	0·701
40	60	0·263	0·693
30	70	0·213	0·708
20	80	0·253	0·679
10	90	0·237	0·693
0	100	0·199	0·722

ALLOYS of COPPER and ZINC.

Percentage of Copper.	Percentage of Zinc.	Electromotive Force in Volts.	
		With Water.	With Dilute Sulphuric Acid.
100·00	0·00	0·031	0·153
91·92	8·08	0·037	0·130
85·75	14·25	0·053	0·150
72·99	27·01	0·162	0·153
66·70	33·30	0·199	0·176
49·32	50·68	0·330	0·206
27·99	72·01	0·408	0·432
7·53	92·47	0·678	0·768
0·00	100·00	0·709	1·442

For the lead and tin alloys, it would appear from the first Table that no definite law can be deduced. The last Table shows that in acid-solutions the electromotive force of alloys is determined by the proportional part of that metal which is most readily attacked by the acid.

E. H.

Determination of the Coefficients of Elasticity of Copper.

By W. VOIGT.

(Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, vol. xxxvii., 1883, p. 961.)

In determining the coefficients of elasticity of metals the chief difficulty lies in obtaining a really homogeneous and isotropic sample of the material. In the case of some metals pieces can be obtained, which may be regarded as internally homogeneous, by pouring out large masses in a molten state and allowing them to cool very slowly. The Author considers that samples formed by electrolytic deposition will also give good results, and has experimented on bars of copper obtained in this way. In previous experiments on glass bars the Author had observed a difference of elasticity according as the bar was cut from the plate with its axis of greatest breadth normal or parallel to the plane of the plate. Similar differences in the coefficients of torsion, amounting to about 20 per cent., appeared in the copper, showing that it should be regarded as crystalline in structure rather than isotropic.

Assuming that the crystals are arranged in a particular manner, the Author shows that the theory of hexagonal crystals is applicable, and calculates the coefficients of elasticity for the several axes from his experimental results. It is then possible to deduce therefrom the coefficients of elasticity of the material assumed to be isotropic. The coefficients of bending and torsion obtained in this way are respectively 11,630,000 and 4,650,000, taking the gram and millimetre as the units of mass and length. The former lies midway between Wertheim's results for drawn and annealed copper wire at a temperature of 15° to 20° Centigrade, viz., for drawn wire, 12,450,000, and for annealed, 10,520,000. The value obtained for the coefficient of torsion is much greater than Wertheim's, but is in closer agreement with Savart, who finds 4,200,000.

E. H.

A Bichromate of Potash Battery—a Light Electro-motor.

By Gaston Tissandier.

(Compte-rendu de l'Association française pour l'Avancement des Sciences, 1882, p. 231.)

The Bichromate battery, as generally set up, becomes very soon polarised, and consequently is not adapted for producing a constant current. The Author has, however, constructed a battery of this class which gives very promising results. Each element consists of a rectangular ebonite trough containing ten thin zincs and eleven carbons, mounted parallel on the rods which support them. The weight is thus distributed—

Zincs	1,206	grams.
Carbons	900	„
Ebonite trough	860	„
Liquid (about 4 litres) . .	4,800	„
Accessories.	200	„
Total . .	7,966	„

The composition of the liquid is—

Water	100	parts.
Bichromate	16	„
Sulphuric acid	37	„

with the addition of a small quantity of bisulphate of mercury for maintaining the amalgamation of the zinc. The liquid is thus very concentrated, which has the effect of diminishing the resistance of the element, and avoiding the dead weight of water. The electromotive force of the element is 2 volts, and the internal resistance 0·01 ohm. A battery formed of eighteen elements in series weighs 140 kilograms, and will give a current of 50 amperes for an hour and a half, through a resistance of 0·54 ohm. The power obtainable in the external circuit is thus 135 kilogram-metres per second, of which a suitable motor, weighing about

50 kilograms, should be able to transform 100 kilogrammetres per second into useful work. Hence, with a gross weight of 200 kilograms, it is possible to obtain 100 kilogrammetres per second of available energy for at least ninety minutes.

The Author hopes to be able to apply this generator and motor to working a screw for propelling a balloon. A screw 2·80 metres in diameter, with two helicoidal blades, as in Victor Tatin's design, should not weigh more than 7 kilograms. A hydrogen balloon of an elongated form, 27 metres long and 9 metres in diameter, would have a net lifting capacity of about 600 kilograms; hence this leaves approximately 400 kilograms available for the weight of the aeronauts and necessary ballast. The Author believes that a speed of 4 metres per second could be attained in calm weather.

E. H.

On a New System of Electrical Generators. By Dr. Brard.

(Compte rendu de l'Association française pour l'Avancement des Sciences, 1882, p. 244.)

In the combustion of carbon in air, the chemical action taking place consists in general of a single combination, whereas the majority of electro-chemical reactions are double, consisting of a decomposition and subsequent recombination. There is, therefore, small probability of obtaining a useful means of generating electricity by the direct combustion of carbon. The author has turned his attention to the oxidation of carbon, both in a black and incandescent state, by means of certain nitrates and chlorates, and has arrived at the following results:—

1. If a carbon heated to redness, be plunged into a bath containing a nitrate in fusion, a current is generated from the bath to the carbon in the exterior circuit.
2. Nitrates in a state of fusion become very fluid, and acquire the property of wetting the heated substances with which they come in contact.
3. To obtain a current, it is unnecessary to plunge the carbon into the nitrate; it is sufficient to place the vessel containing the nitrate on the heated carbon.
4. Nitrates in a state of fusion are exceedingly stable, and do not decompose at a temperature below 1,000° to 1,200° Centigrade. They do not attack the vessel containing them, but appear rather to retard its oxidation by the fire.

The Author, proceeding on these principles, has constructed a battery in the following manner. On an agglomerate of ordinary carbon is placed a mixture of a nitrate and cinders, in the proportion of one to two, and separated by a thin sheet of asbestos paper. The poles of the element are formed by metallic threads traversing the carbon and nitrate. If such a battery be placed in the fire, the carbon reddens, and the nitrate fuses, a current is then established, at first feeble and then stronger, until it attains a maximum value, at which it continues as long as the combustion is maintained. A battery 15 centimetres long, 3 centimetres in breadth and thickness, weighing 220 grains, of which 120 consisted of carbon, 35 of the nitrate salt and 65 of cinders, burning for two hours, gave an electromotive force, varying from 0·9 to 1·2 volt; the internal resistance of the battery being 1·20 to 0·80 ohm. The resistance of the same element when cold was 104·500 ohms. The author hopes to be able to diminish the resistance by getting rid of the asbestos sheet, and to increase the electromotive force by mixing chlorates with the nitrates, since their oxidising power is superior.

E. H.

On the Local Action of the Zinc Poles of Electrical Batteries when on Open Circuit. By EMILE REYNIER.

(L'Électricien, 1883, p. 296.)

No experiments on this subject having come under the Author's notice, and doubts being sometimes entertained as to the advantage of amalgamating zinc electrodes, the experiments, the results of which are tabulated below, were undertaken to decide this question. Rods, similar to Leclanché poles, composed of ordinary zinc, zinc amalgamated with mercury (the zinc taking up about ½ per cent. of its weight), and an alloy of 96 parts zinc and 4 of mercury were immersed in the various liquids ordinarily used in cells, and the loss of weight determined after a given time.

It is evident, therefore, that the amalgamation is of immense importance; and further that the alloy of zinc and mercury, especially in batteries furnishing a strong current, presents such considerable advantages, as to render it advisable to substitute it for the ordinary zinc in all batteries, being at the same time more economical, as it dispenses with the labour required for frequent re-amalgamations. The use of pure sulphuric acid, or, what is cheaper, ordinary acid treated with oil by d'Arsonval's process[1], also reduces the local action in the case of the amalgamated and alloyed zincs. In the chromic solutions the use of ordinary zinc is impracticable, and even the consumption of amalgamated zinc increases rapidly with the duration of the immersion, while it becomes covered with a greenish film, the alloy on the other hand remaining bright and clean. The alloy is more brittle than ordinary zinc, but where necessary any difficulty arising therefrom could be overcome by filling it in gratings of a stronger material.

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[1] *Vide* "Formulaire pratique de l'électricien."

RESULTS of EXPERIMENTS.

Composition of the Liquid.			Duration of Experiment.		Consumption of Zinc per Hour in Grams per Square Centimetre.		
			H.	M.	Ordinary.	Amalgamated	Alloyed.
Water	by volume	90	1	0	2,965	..	..
Ordinary sulphuric acid (66°)	„	10	2	0	..	54	7
Water	„	90	1	0	1,918	..	..
Pure sulphuric acid (66°) .	„	10	48	0	..	0·2	0·3
Water	„	90	1	0	235	..	..
			1	40	898	..	..
Ordinary sulphuric acid, treated with oil by d'Arsonval's process	„	10	2	25	1,522	..	..
			72	0	..	0·6	0·8
Water	„	90	1	0	3,794	..	..
Ordinary sulphuric acid (66°)	„	10	24	0	..	12	8
Nitrate of soda . . .	grains per pint	88	51	0	..	73	26
Water	by weight	1,000	24	0	83	..	..
Bisulphate of potash . . .	„	100	72	0	..	0·2	0·1
Water	„	1,000	24	0	65	..	..
Bisulphate of potash . . .	„	100	72	0	..	Nil	Nil
Sulphate of ammonia. . .	„	50					
Water	by volume	90	1	0	4,698	4,244	..
Ordinary sulphuric acid (66°)	„	10	1	20	..	..	2,393
Sulphate of copper . .	grains per pint	438					
Water	by weight	1,000	24	0	117	44	57
Sulphate of copper . . .	„	150	49	0	..	78	85
Water	„	1,250	0	30	7,810	..	..
Bichromate of potash .	„	200	0	40	..	1,532	..
Ordinary sulphuric acid (66°)	„	470	1	20	..	1,991	..
			2	50	..	..	1,334
Commercial hydrochloric acid			0	15	19,665	..	..
			24	0	..	183	34
Water	by volume	800	1	0	4,556	..	..
Commercial hydrochloric acid	„	200	72	0	..	2·6	0·9

F. J.

On a Liquid for maintaining a Constant Current in a Carbon-Zinc Battery. By RUDOLF HANDMANN.

(Centralblatt für Electrotechnik, 1883, p. 424.)

The Author's experiments on the ordinary Bunsen element, *i.e.*, carbon in pure nitric acid and zinc in dilute sulphuric acid, showed that, when the circuit was closed through an external resistance equal to the internal resistance of the cell, the current fell after seven hours to 81 per cent. of its primary value; if, to avoid the noxious fumes of nitrous oxide, the nitric acid be replaced by a solution composed of 100 parts sulphuric acid, 80 parts of bichromate of potash, and 1,000 parts water, then in two hours' time the current had fallen to 36 per cent. of its original value, and with a stronger solution of 100 parts acid, 300 water, and 60 of bichromate of potash, the value after the same interval was 51·7 per cent. A single fluid element of the same solution as the last, and without a porous cell, fell in two hours to 39 per cent.

The improved solution proposed by Mr. M. Egger emits no noxious fumes, and is composed of

200 parts sulphuric acid,
25 to 50 „ bichromate of potash,
100 „ nitric acid (34 per cent.),
200 „ water,

and gives most favourable results, as the following figures show, for with the smaller amount of bichromate the current remained practically constant for four hours, and had after fifteen hours on closed circuit fallen only 13 per cent. from its first value, and with the larger amount of bichromate had after seventeen hours fallen only 10 per cent.

The constancy of the Wollaston dipping-battery is of very short duration, but Mr. Egger has observed that the copper plates become, after drying in the air, covered with a blackish film, and on the first subsequent introduction into the liquid a current of very high electromotive force, but of correspondingly short duration is furnished. This fact may point to a means of forming a powerful primary element.

F. J.

Laws of Induction. By — QUET.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, pp. 639-641.)

This Paper relates to the laws of induction due to the variation of quantity in the case of circular currents. When the dimensions of the system are very small, the force is perpendicular to the plane passing through the centre of the induced mass and the axis of the inductor system; for plane circuits and cylindric and spheric solenoids, the force

$$F = \frac{k}{2} m p \frac{d i}{d t} \frac{w \sin e}{R^2},$$

in the case of a single plane current, w is the area of the circuit; R the distance of the centre of gravity of this area to the induced mass m; e the angle that R makes with the normal to the circuit, and $p = 1$.

For an electro-dynamic cylinder, R is taken from the centre of the cylinder, and p designates the relation of the length, L, of the cylinder to the distance, l, of the consecutive generatrices.

For a spheric solenoid, R is taken from the centre of the sphere; w is the area of a great circle, and p is proportional to the ratio existing between the radius and the arc l of great circle intercepted by two consecutive and perpendicular generatrices.

The formula shows that the decrement of force due to increment of distance is less rapid with electro-dynamic, or magnetic action of permanent currents. This formula has great analogy with that giving the action of an element of current on a magnetic pole.

When the dimensions of the current are not very small, the law is less simple: its general form is—

$$f = -\frac{k}{2} m \frac{d\,i}{d\,t} \frac{d\,s \cos\theta}{r} = -\frac{k}{2} m \frac{d\,i}{d\,t} \frac{d\,r}{r} = h \frac{d\,r}{r}.$$

The Author applies this general formula to a particular case of circular currents, and arrives at a formula coinciding with that first given.

P. H.

On Induction. By P. LE CORDIER.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, pp. 625–627.)

The idea of a continuous and incompressible medium, the translations and the pressure of which produce currents and electrostatic phenomena, is adopted by the Author, not as a hypothesis, but as an image leading more simply than any other to the laws to be established. These laws are restricted to the case where the time of propagation of the induction flux is negligible. The electromotive force of induction in a rheophore of three dimensions is resolved into two others, one of which produces current, the other electrification. The free electricity is distributed partly in the volume and partly in the surface. The equations determining cubic and superficial density are given. The Author deals with the coefficient of self-induction of a tonic wire, in which μ, the coefficient of magnetic permeability, is $= 1$ for a tonne of copper, and $\mu = 500$ for a tonne of soft iron. If the intensity of nduced currents in the soft iron were proportional to that which Maxwell has termed magnetic force, μ would $= 1$ instead of $= 500$.

The coefficient of self-induction per unit of length of an indefinite system, composed of two soft iron wires, rectilinear and parallel, of the same radius a, traversed in opposite directions by the same current, is, c being the distance between the axes of the two wires, and μ their magnetic permeability,

$$L_1 = 4\left(\frac{u}{z} + \log_e \frac{c}{a} + \frac{\mu - 1}{\mu + 1}\frac{a^2}{c^2}\right).$$

The coefficient of self-induction per unit of length of an indefinite system of two cylindric conductors, hollow and concentric, traversed in opposite directions by the same current, of magnetic permeabilities μ_1 and μ_2, and of radii a, b, c, d, commencing at the smallest, is—

$$L_1 = 2\log_e \frac{c}{b} + \mu_1 - \mu_2 + \mu_1 \frac{a^2}{b^2 - a^2} \log_e \frac{b}{a} + \mu_2 \frac{2\,d^2 - c^2}{d^2 - c^2} \log_e \frac{d}{c}.$$

If one or the other of the two preceding systems were found advantageous for telephonic transmission, there would be an interest in diminishing L_1, and the substitution of copper for iron would be very useful, for $\frac{c}{a} = 3$, and, by preserving that ratio, L_1 would be made about 156 times smaller. L_1 in the last equation may be made nil in any metal by properly choosing the four radii, but the condenser action would be in the way of telegraphic transmission.

P. H.

On the Induction due to the Variation in Quantity of an Electric Current in a Plane Circuit and in a Cylindric Solenoid.

By — Quet.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, pp. 704, 992.)

The Author has previously given a very general formula representing the inductive force produced by the variation of quantity in a circular electric current, applicable to the Ruhmkorff coil and analogous coils. This formula is extended to plane circuits, and to the case of a cylindric solenoid, and in the latter instance formulæ are deduced closely representing the first and second of Biot and Savart's laws of electro-magnetism. The mathematical consideration scarcely admits of condensation.

Considering the potential of the force of induction due to a closed solenoid, in which the quantity of current varies, the Author arrives at a close analogy with the following general theorem in the case of this kind of solenoid, and he finds support from Felici's experiments. The theorem is, that the potential of the force of induction due to a closed solenoid, and in which the current is varied in intensity is, other things equal, proportional to the angle under which the directrix is seen from the point of application of the force. An extended mathematical proof is given.

P. H.

On the Effect of Pressure on the Electromotive Force of a Reversible Element. By F. Niemöller.

(Annalen der Physik und Chemie, No. 3, 1883, p. 429.)

It is clear that the pressure of the fluid in a cell must have some effect on the electromotive force; for, consider a current passing through a single-fluid cell and forming a salt in the solution, the fluid becomes more elastic through the formation of the salt, and consequently expanding, does work; the amount of work done in this way increases with the pressure. The electrical equivalent of this work must be represented by a fall in the electromotive force of the element.

Let s be the weight of the salt in solution, w the weight of the water, v the volume, p the pressure, and θ the absolute temperature which is maintained constant. Then if F be the free energy of the fluid

$$-\frac{d\,\mathrm{F}}{d\,v} = p = \frac{v_0 - v}{\mu\, v_0} \quad . \quad . \quad . \quad . \quad (1)$$

where v_0 is the volume of the fluid when $p = o$ and μ is a constant depending on the concentration. If E be the part of the electromotive force which depends on the concentration, and q the quantity of salt deposited by the unit of electricity, then, since the loss of energy in the current must equal the gain in the fluid,

$$-\frac{d\,\mathrm{F}}{d\,s}\,q = \mathrm{E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Now put $w = sh$, then μ is a function of h only; hence, differentiating (1) and (2) with respect to s and v respectively.

$$\frac{d\,\mathrm{E}}{d\,v} = q\,h\,\frac{v_0 - v}{v_0\,\mu^2 s}\cdot\frac{d\,\mu}{d\,h}.$$

If σ is the specific gravity of the solution,

$$\sigma\, v_0 = w + s = s\,(1 + h).$$

Hence,

$$\frac{d\,\mathrm{E}}{d p} = \frac{d\,\mathrm{E}}{d\,v}\cdot\frac{d\,v}{d\,p} = -\frac{p\,q\,h\,v_0}{s}\,\frac{d\,\mu}{d\,h} = -\frac{p\,q\,h\,(1+h)}{\sigma}\cdot\frac{d\,\mu}{d\,h}.$$

and by integration,

$$\mathrm{E} = \mathrm{E}_0 - \frac{p^2\,q\,h\,(1+h)}{2\,\sigma}\,\frac{d\,\mu}{d\,h}.$$

The change in the electromotive force is therefore proportional to the square of the pressure.

The Author considers the effect might be observable with a pressure of 30 to 40 atmospheres.

A similar effect should occur in a single-fluid reversible cell, where the electrodes are of the same metal, but the concentration of the fluid greater at the one than at the other. Such a cell should generate a current through the liquid from the less concentrated to the more concentrated part of the liquid.

E. H.

Some Formulas Relative to the Distribution of Electricity.

By GEORGES GUEROLT.

(La Lumière Electrique, vol. x., 1883, pp. 389–391.)

1. General formula for the total resistance in an electric distribution in multiple arc, analogous to a distribution of gas:—R is the resistance of the group. If there is only one lamp, R is the resistance of that lamp; if there are several, R is the reduced resistance of the group. r_1, r_2, r_3 . . . r_n are the resistances of the branches of the conductors, and R_1, R_2 . . . R_n the total resistances of lamps and conductors combined, to the 1st, 2nd, and *n*th lamps starting from L_1 (in the accompanying diagram L_1 is the most distant lamp from the machine). From the consideration of the general law of the reduced resistance of joint-derived circuits the Author obtains the general formula:

$$R_n = \frac{R + r_1 + 2\,r_2 + 3\,r_3 \ldots\ldots\ldots\ldots + n\,r_n}{n + \frac{1}{R}\left[(n-1)\,r_1 + (n-2)\,2\,r_2 + (n-3)\,3\,r_3 \ldots + r_{n-1}\right]}$$

This formula is much simplified if $r_1 = 2\,r_2 = 3\,r_3 \ldots = n\,r_n$. It then takes the following form:

$$R_n = \frac{R + n\,r_1}{n + \frac{r_1}{R}\left[(n-1) + (n-2) \ldots\ldots + 1\right]}$$

or,

$$\frac{R + n\,r_1}{n + \frac{r_1}{R}\,\frac{n\,(n-1)}{2}}.$$

If $\frac{r_1}{R}$ is put $= \epsilon$, $R_n = \frac{R}{n} \cdot \frac{2\,(1 + n\,\epsilon)}{2 + (n-1)\,\epsilon}$. $\frac{R}{n}$ is the reduced resistance of all the lamps, supposed in multiple arc. The fraction $\frac{2\,(1 + n\,\epsilon)}{2 + (n-1)\,\epsilon}$ whatever n and ϵ may be, is always comprised between 1 and 2; whence the following theorem:

In a system of conductors such that the resistance increases in arithmetic progression from the first lamp to the last, the total resistance at a given division, is greater than the reduced resistance of all the lamps situated beyond this division, and smaller than twice this resistance. But it is necessary that the electromotive force should go on increasing, starting from the last lamp. Designating by I_n and I_{n+1} the quantities of current corresponding to the total resistances R_n and R_{n+1}, and by i the current in the lamp, this condition is expressed by the inequality $I_n R_n < I_{n+1} R_{n+1}$, or $n\,i\,R_n < (n+1)\,i\,R_{n+1}$, or finally, substituting for R_n and R_{n+1} the values deduced from a foregoing formula and completing the reduction $\epsilon\,(e-1) < 0$, which can be satisfied only if ϵ on $\frac{r_1}{R}$ is < 1. It is thus necessary that the branches of the conductors of the last section have a resistance less than the resistance of the lamp or of the group.

2. Calculation of the electromotive force and of the work in each division of the conductor. Let i be the current, and e the electromotive force at the terminals of the last lamp, and E_n the electromotive force sought. $\frac{E_n}{R_n} = n\;i = n\;\frac{e}{R}$, whence $\frac{E}{e} = n\;\frac{R_n}{R} = \frac{2 + 2\,n\,\epsilon}{2 + (n-1)\,\epsilon}$. The total work effected in the portion of the circuit beyond the nth division is equal to $\frac{n^2\,i^2 \times R_n}{g} = \frac{n\,i^2\,R}{g} \cdot \frac{2 + 2\,n\,\epsilon}{2 + (n-1)\,\epsilon}$.

In a branch of the conductor at the rung or derivation p, the work is $\frac{p^2\,i^2 \times r_p}{g}$. But by the hypothesis, $r_p = \frac{r_1}{p} = \frac{e\cdot R}{p}$. Substituting $r\,p$ by its value, the work due to heating the branch p is $\frac{p\,i^2\,R\,\epsilon}{g}$. The sum of the analogous works for the different branches from 1 to p is represented by $\frac{i^2\,R\,\epsilon}{g}\,\frac{p\cdot(p+1)}{2}$. The work in the lamps alone, at the nth division, is

$$\frac{n\,i^2\,R}{g}\left(\frac{4 + 2\,(n-1)\,\epsilon - (n^2-1)\,\epsilon^2}{2 + (n-1)\,\epsilon}\right).$$

3. Calculation of ϵ. To determine $\epsilon = \frac{r_1}{R}$ or the modulus of the conductor system the following method may be pursued, the different branches being supposed all of the same length. The superior limit of temperature that the branch conductor may attain is the fusion point of the insulating material, or T. By reduction and substitution this temperature should be at the end of h seconds, where l is the length of wire, inferior to T; ϵ

must satisfy the inequality $\frac{5027\,l_1^2}{i^2\,\epsilon^2\,R^2 \times 10^5 \times h} < T$, whence $\epsilon^2 < \frac{502\cdot7\,l_1^2\,T}{i^2\,R^2 \times h \times 10^4}$, or $\epsilon = \frac{0\cdot22\,l}{i\,R}\sqrt{\frac{T}{h}}$.

If this value of ϵ be inserted in the expression for R_n,

$$R_n = \frac{R}{n}\left(\frac{2 + n \times 0\cdot44\,\frac{l}{i\,R}\sqrt{\frac{T}{h}}}{2 + (n-1)\,0\cdot22\,\frac{l}{i\,R}\sqrt{\frac{T}{h}}}\right).$$

Expressed in function of ϵ, the weight $P_2 = 0\cdot0006\,i_1\,l_1\sqrt{\frac{h}{T}}$. If all the branches are of the same length, the total weight is equal to

$$P_1\,(1 + 2 \ldots . n) = 0\cdot0006\,i_1\,l_1\sqrt{\frac{h}{T}} \cdot \frac{n\,(n+1)}{2}.$$

The total weight of conductors is thus proportional to the current quantity; to the length of each branch, to the square root of the duration of lighting; approximately to the square of the number of lamps or groups, and inversely proportional to the square root of the fusion-point of the insulating substance.

P. H.

General Method for the Installation of Electric Lighting by means of Incandescence-Lamps.

By Adolphe Minet.

(La Lumière Electrique, vol. x., 1883, p. 246.)

The most important point is to determine the quantity of current necessary for each lamp for a given luminous intensity. Mr. Jamieson's experiments led him to suppose that the luminous intensity increases as the cube of the work expended, and the curves he has drawn are taken from the formula $L = a\,(a)^3$, where L is the luminous intensity in normal candles; a the actual work in the lamp expressed in volt-amperes; a a coefficient which represents the luminous intensity per volt-ampere. As $a = \epsilon\,i$, and as ϵ, the potential difference, may be expressed as a function of the resistance (hot) of the lamp, $\epsilon = ri$, $a = ri^2$, and $L = a\,(ri^2)^3$, whence the current necessary to the lamp for a given luminous intensity L is $i = \sqrt[6]{\frac{L}{a\,r^3}}$. Dr. Voit has determined a for twenty-two types of lamps; and from a very extended Table it appears that this coefficient varies from 0·00003 to 0·000136, whilst i varies from 0·613 to 1·815 for ordinary sizes of lamps. Taking for r the values representing half the resistance (cold) of the lamp, the error will be within 2¼ per cent.

P. H.

Luminous Efficiency in Incandescence-Lamps relatively to the Work absorbed by the Lamps and the Machine.

By Adolphe Minet.

(La Lumière Electrique, vol. x., 1883, p. 282.)

The luminous efficiency of a lamp is given by the ratio of the intensity of light emitted to the work absorbed by the lamp. The quantity of light emitted for the expenditure of a kilogrammetre is expressed by $c = \frac{g\,L}{r\,i^2}$, an expression that admits of the comparison of lamps of different types. In a previous article[1] the Author has justified Jamieson's equation $L = a\ (r\ i^2)^3$, and by substitution $c = \frac{a\,g\,(r\,i^2)^3}{r\,i^2} = a\,g\,(r\,i^2)^2$, which shows that luminous efficiency is proportional to a constant factor g, a coefficient a varying with each type of lamp, to the square of the resistance (cold) of the lamp, and to the fourth power of the current. A Table is given representing the quantity of energy expended in an Edison 7 B lamp for intensities of light varying between 5 and 50 normal candles, with the corresponding luminous efficiency. To find the luminous efficiency of any known lamp for a given intensity of light, it is sufficient to multiply the corresponding figure for the Edison 7 B lamp by the coefficient K, that has been determined for all the lamps known at the present day. $K = \sqrt[3]{\frac{a'}{a}}$, where a' is the coefficient varying with each lamp, and a that of the Edison 7 B. The following is a very condensed abstract of the first Table, and the second Table is condensed from the full data given for thirty lamps:—

Edison 7 B Lamp. Resistance hot, 60 ohms.

Luminous Intensities L.	Force absorbed in Kilogrammetres t.	Efficiency. Luminous Intensity per Kilogrammetre $c = \frac{L}{t}$.	Current in Amperes i.
5	3·17	1·58	0·720
10	4·08	2·46	0·817
15	4·75	3·16	0·882
20	5·30	3·78	0·930
25	5·78	4·34	0·972
30	6·18	4·87	1·005
35	6·54	5·35	1·034
40	6·81	5·89	1·058
45	7·14	6·29	1·081
50	7·42	6·73	1·103

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[1] *Ante*, p. 410.

Experiments.	Lamp.	Luminous Intensity.	Resistance Hot.	Current Amperes.	Luminous Intensity per Kilogrammetre Measured.	Coefficients.	
						a.	K.
Commission of Exposition, 1881.	Edison A .	15·38	137·4	0·651	2·60	0·000079	0·834
	Swan A . .	16·11	32·78	1·471	2·28	0·000050	0·717
	Lane-Fox A.	16·36	27·40	1·593	2·33	0·000049	0·711
	Maxim A .	15·96	41·11	1·380	2·01	0·0000336	0·627
Jamieson.	Edison 7 B .	21·3	59·3	0·948	3·93	0·000136	1·0
	Lane-Fox .	30·0	95·0	0·838	4·39	0·000098	0·896
	Maxim . .	24·3	38·2	1·380	3·30	0·000066	0·787
	Swan. . .	23·7	31·8	1·47	3·38	0·000073	0·813
Committee Exposition Munich.	Edison A .	18·47	158·3	0·678	2·48	0·000047	0·707
	Maxim L .	17·97	48·46	1·34	2·01	0·0000248	0·568
	Swan . .	18·33	83·58	1·161	1·60	0·0000114	0·438
	Siemens No. 1	17·15	101·0	0·946	1·86	0·0000233	0·556
	Small Müller	17·66	59·67	1·189	2·06	0·0000286	0·595
	Cruto . .	19·69	8·17	3·26	2·23	0·0000325	0·621

P. H.

On the Variation of the Economic Coefficient in Dynamo-electric Machines. By Adolphe Minet.

(La Lumière Electrique, vol. x., 1883, p. 306.)

The Author, in a previous examination of a general method of installing a system of electric lighting, employed a factor ϕ, which he terms the reduction-coefficient of the luminous efficiency of the machine. This coefficient is the ratio between the work τ_1 expended in the whole of the lamps, and the total energy T of the machine, or $\phi = \frac{\tau_1}{T}$. Let c be the quantity of light emitted in standard candles for the expenditure of a kilogrammetre. For the same quantity of energy developed by the machine, the luminous intensity C becomes $= c\ \phi$. The total energy T engendered by the machine appears as two kinds of work, useful work expended in the external circuit and that expended as heat in the interior of the machine. If t is this loss of energy, $T = t + \tau$. Referring the total internal work t to the total work engendered by the machine $\phi_1 = \frac{t}{T}$, whence $t = \phi_1\ T$. Replacing t and τ by their equivalents $T = \phi_1\ T + \phi\ T$, and eliminating T, $1 = \phi_1 + \phi$. The coefficient ϕ_1 may be termed the complement of the economic coefficient of the machine. From the works expressed as heat, the Author deduces that $\phi_1 = \frac{r}{E} I$, where I is the quantity of current, R the total resistance, and r the resistance of the machine. The Author applies these and some deduced formulas to the comparison of the following machines:—

	Economic Coefficient $\phi = 1 - \phi_1$.
Gramme plating machine	52·5
" A " (strengthened)	73·1
" A " (workshop type)	77·0
" D " (modified by Marcel Deprez)	49·0
Siemens D_0 machine	76·2
" D_1 "	71·9
" D_2 "	77·6
" D_5 "	66·9
" D_6 "	43·6
Marcel Deprez's machine (M. D. 10)	88·8

The last machine, at 1,000 revolutions, and with 6 amperes of current, gave, as work in the external circuit, 21·2 HP. for a total energy engendered by the machine of 24 HP., with a mechanical efficiency of 89 per cent. At a velocity of 1,200 revolutions and 5 amperes of current this machine developed 24 HP., and the external circuit furnished a useful work of 22·1 HP., or an efficiency of 92 per cent.

P. H.

A New Capillary Electrometer. By A. Chervet.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, pp. 669–672.)

This apparatus will evaluate a difference of potential smaller than 0·9 Daniell, with an approximation of 0·001 Daniell. It can be easily constructed. Two flasks, tubulated laterally, contain the one, A, mercury; the other B, some mercury and water acidulated with one-tenth the sulphuric acid by volume. A thermometer-tube connects the flasks, and is enlarged towards A. A platinum wire, insulated in a piece of glass tube, makes contact with the mercury, but not with the acidulated water in B; another platinum wire connects the mercury in A. The wire in B is always to be positive. The heights of the mercury in A and B are such that the wires being connected, the surface of separation of the two liquids is found in the enlarged part of the thermometer-tube, as nearly as possible the capillary part. Let a be the angle of the cone tangent to the surface of the tube at the point where the meniscus occurs; a is a very small angle; let a be the capillary depression, and r the radius of the tube, $a = \frac{M}{r}$, where M is a quantity which depends on the difference of potential V intercalated between the two wires. If V = 0·001 Daniell, M increases $\frac{1}{750}$ of its value;[1] let x be the corresponding displacement, the radius of the tube becoming $r + x \sin a$, and

$$a = \frac{M}{r} = \frac{M + \frac{1}{750} M}{r + x \sin a} = \frac{\frac{1}{750} M}{x \sin a}, \text{ whence } x \sin a = \frac{r}{750}.$$

If $a = 0 \cdot 01$ metre, $r = 0 \cdot 00045$ metre; the displacement x, to be visible to unaided eye, should be greater than $0 \cdot 0002$; then $\sin a =$ about $10'$.

With these dimensions the eye can perceive a difference of potential $= \frac{1}{1000}$ volt; and with a lens a difference of $\frac{1}{10.000}$ volt. The potential difference can be measured with this accuracy by compensating with a water manometer; and to calibrate the apparatus a known difference of potential of 0·0001 Daniell is taken, for which the pressure evaluated in mercury is $\frac{1}{7500}$ part of the capillary depression as found by Lipmann, and measured on the water manometer it will be 13·5 times greater. The potential can be calculated from Lipmann's Tables.

P. H.

New Method of Insulating Wire. By C. WIDEMANN.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., pp. 852–853.)

The Author has observed that objects decorated in baths of plombates and alkaline ferrates by Nobili's process, becomes absolutely resisting to all galvanic action, that is, the surface once covered with peroxide of lead or of iron is insulating. The application has been made to the insulation of wires; the method of preparation is simple. A bath of plombate of potash is prepared by dissolving 10 grms. of litharge with 200 grms. of caustic potash in a litre of water, and boiling for about half-an-hour; the liquid is decanted, and is used as an electrolytic bath, the wire to be covered being attached to the positive pole, a small plate of platinum being arranged to receive the lead deposited at the negative pole. The insulation is perfect only when the wire has attained its last tint, a brown black.

P. H.

On the Change of Phase in a Periodic Current due to Polarisation. By A. WINKELMANN.

(Annalen der Physik und Chemie, No. 9, 1883, p. 91.)

F. Kohlrausch has shown that the polarisation of an electrolyte through which an alternating current is passed affects both the phase and the strength of the current. In his experiments a sine-

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[1] Lipmann, "Annales de Chémie et de Physique," 5th series, vol. v.

inductor was used; in the Author's experiments the periodic current was obtained by an induction-coil in which the primary circuit was periodically broken and closed by means of a tuning-fork arrangement. The current from a battery was taken through an electric tuning-fork A, alternately making and breaking the circuit, then round the primary circuit of the induction coil and back to the battery. From this circuit a shunt was derived between the coil and the battery through a second electrically maintained tuning-fork B, carrying the object-glass of a microscope. The coils of the secondary circuit were connected through a switch, by which either an ordinary resistance W, or an electrolyte in which the polarisation was considerable, could be thrown into the circuit. The secondary circuit also included a third tuning-fork C, carrying a silver head illuminated by a properly situated lamp, and placed in such a position that it could be viewed by the microscope. For the polarising liquid either dilute sulphuric acid or saturated brine was used, the electrodes being of bright platinum from 20 to 45 square millimetres in area. The shunt circuit including the fork B was so arranged that the amplitude of vibration was about the same as that of the fork C. The bright spot then appeared to describe an ellipse. By weighting the prongs of B or C the ellipse could be made to pass into a straight line. If the resistance W was increased the straight line slowly changed into an ellipse, whose minor axis increased, while its major axis decreased and at the same time rotated, so as to more nearly approach a horizontal position. If the polarisable liquid were substituted for W in the induction-circuit, a change of curve took place, which might be due to a change of resistance; but a resistance W could be found, such that when the switch was reversed the major axis of the ellipse decreased, and at the same time approached the perpendicular. This effect must be wholly due to change of phase.

E. H.

A New Aperiodic Galvanometer. By G. Le Goarant de Tromelin.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, p. 995.)

If a third needle is added to an astatic galvanometer below the frame and parallel to the two others, and with poles of contrary name to those of the needle above it, the sensitiveness is very nearly tripled, and a directive force is preserved. The arrangement may be reversed; the frame rendered movable, and into which the current arrives by the suspension-wires, and the needles fixed. These considerations led the Author to the construction of the following instrument, in which six poles are preserved, but these poles are formed by three horseshoe iron magnets, with closely-approached arms. The three magnets are fixed horizontally, one above the other, at a distance of 5 millimetres. The frame surrounds the two poles of the middle magnet, with sufficient play to admit of free oscillation to 20° on each side. The wire of the very light frame is perpendicular to the axis of the magnets, and is suspended as in Sir W. Thompson's siphon-recorder. The galvanometer is extremely sensitive and perfectly aperiodic. If the position of the lines of force be examined with regard to the four sides of the frame, it is to be seen that electro-magnetic induction is produced on all the four sides, and in the same direction.

P. H.

Verification of Laws relating to Galvanometers.

By T. du Moncel.

(La Lumière Électrique, vol. ix., 1883, pp. 449.)

In a previous series of articles, the Author has pointed out the laws of electro-magnets, and reported the experiments made for their verification. He now undertakes the same work for galvanometers, and commences with a reference to the formula giving the length of wire on an electro-magnet, which becomes $\frac{a\,b}{g^2}\,[(a+c)\,\pi + 2\,d]$ in the case of the galvanometric multiplier, by reason of the parts d comprised at the turns. a is the depth of layers of the helix of the multiplier; b the width of the frame; c the thickness of the frame, in the interior of which the needle is suspended, and on which the wire is wound; g the diameter of the covered wire; d the distance separating the two curved parts of the frame; R the resistance of the external circuit in terms of length of helix; E the electromotive force of the battery. When a is taken as variable, the most advantageous effect is obtained, when the galvanometer-resistance exceeds that of the external current in the ratio of 1 to $\frac{\pi\,(a+c) + 2\,d}{\pi\,a}$. With sensitive galvanometers this ratio is considerable. The Author concludes from many experiments, the numerical results of which are given, that the external resistance for a given galvanometer, should be much inferior to that of the galvanometer-coil, especially if the circuit is perfectly insulated. That if the circuit is badly insulated or has derivations, the maximum sensitiveness of a galvanometer will correspond to a circuit of which the total resistance, starting from the galvanometer and with its derivations, will be much inferior to that of the helix. That in experiments made with a galvanometer, the extremities of the helix of which are connected by a shunt, it would be preferable to use a galvanometer of low resistance; and that consequently it would be convenient that galvanometers should be mounted with at least two different multiplying helices.

P. H.

On the Magnetic Effect of Electrical Oscillations.

By A. OBERDECK.

(Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, vol. xxxvii., 1883, p. 975.)

Since it is possible by the telephone to transmit the sound of the human voice and musical notes of high pitch with little change of quality, it is evident that the magnetisation of the iron must very closely follow the periodic changes in the magnetising force. It would consequently appear that the magnetic inertia of molecules of iron is very small, when the magnetising forces are weak. The Author has previously employed alternate currents for measuring the self-induction of coils by observing the change of phase in the electrical oscillations due to the induction. If a bar of iron be inserted in the coil, it is clear that the change of phase will be greater; the method therefore is applicable for investigating the magnetic effect of electrical oscillations. Let i be the intensity of the current, then the magnetising force is P i, where P depends upon the dimensions of the coil. If k be the coefficient of magnetic induction, v the volume of the bar, and m its magnetic moment,

$$m = k\,v\,\mathrm{P}\,i,$$

and the electro-magnetic potential of the bar, with respect to the coil, is P m. If p be the potential of the coil apart from the core, the complete expression of the potential is $(p + k\,v\,\mathrm{P}^2)\,i$.

Two methods were employed for determining the value of $p + k\,v\,\mathrm{P}^2$ for a coil 500 millimetres long, wound with 4,200 convolutions of copper wire in five layers, the radius of the inner layer being 19 millimetres, and of the outer 22 millimetres. In the first method the coil, having a resistance of 46 Siemens units, formed one side of a Wheatstone bridge. One adjacent side consisted of an adjustable resistance, and the two opposite sides of equal resistance-coils 56·5 Siemens units each, wound so that their self-induction might be neglected. The bridge was completed by the movable coil of an electro-dynamometer, the fixed coil being in series with a sine-inductor placed in the other diagonal. If the inductor make n revolutions per second, and w_1 be the resistance of the induction coil, w_3 of the equal sides, w_2 the adjustable resistance, and w the resistance of the bridge, then it may be shown that when there is no deflection of the electro-dynamometer,

$$(n\,\pi\,p)^2 = (w_2 - w_1)\,(w_1 + w_2 + w^1),$$

where $$w^1 = \frac{2\,w\,w_3}{w_2 + 2\,w_3}.$$

Let the iron core be now placed within the coil, and let w_1 be the increased resistance necessary to bring back the dynamometer to the zero position, then—

$$(n\,\pi)^2\,(p + k\,v\,\mathrm{P}^2)^2 = ({w^1}_2 - w_1)\;(w_1 + {w_2}^1 + w^1),$$

or

$$\pi\,(p + k\,v\,\mathrm{P}^2) = \mathrm{C}\,;$$

where

$$\mathrm{C} = \frac{1}{n}\sqrt{({w_2}^1 - w_1)\;(w_1 + {w_2}^1 + w^1)}.$$

The experiments were made with cylindrical iron bars 400 millimetres long and of various diameters, either inserted singly or in bundles of several bars, and also with a bundle of a great number of iron wires of about 0·5 millimetre diameter. The quantity C diminished as n was increased in all cases except for the bundle of fine wires for which it remained constant, showing that in general the induced magnetism diminishes as the period of the alternating current is shortened.

After describing a second method of determining the value of the potential function $p + k\,v\,\mathrm{P}^2$, the Author next considers the difference in phase between the magnetising force and the induced magnetisation. To determine this experimentally the current from the inductor was taken through the fixed coil of the electro-dynamometer and through two layers of the induction-coil previously described. A second circuit was formed by the remaining layers of the induction-coil, the movable coil of the electro-dynamometer, and a resistance-box. If there is no deflection of the dynamometer the difference of phase must be $\frac{\pi}{2}$. When the iron was withdrawn from the induction-coil the deflection was too small to be measured. The experiment was then tried with the several bars of iron, in each case with 200 and 400 Siemens units respectively in the adjustable resistance. Let J be the inducing current, then

$$\mathrm{J} = a\cos(n\,\pi\,t)\,;$$

and the induced magnetic moment is

$$m = k\,v\,\mathrm{P}\,a\cos(n\,\pi\,t - \phi).$$

The electromotive force in the second circuit is

$$-\,\mathrm{P}^1\frac{d\,m}{d\,t} = k\,v\,\mathrm{P}\,\mathrm{P}^1\,a\sin(n\,\pi\,t - \phi)\,;$$

and if i be the induced current,

$$w\,i + p\,\frac{d\,i}{d\,t} = -\,\mathrm{P}^1\,\frac{d\,m}{d\,t},$$

where w is the resistance.

The deflection a of the dynamometer is proportional to

$$\frac{1}{T}\int_0^T J\, i\, d\, t;$$

hence $$a = A\,\frac{w \sin\phi + n\,\pi\,p\cos\phi}{w^2 + n^2\,\pi^2\,p^2},$$

where $$A = \frac{k\,v\,P\,P^1\,n\,\pi\,a^2}{2}.$$

Hence taking two values of w and neglecting the second term of the numerator, which is small in comparison with the first, there results for the change of phase—

$$\tan\phi = \frac{n\,\pi\,p}{w_1\,w_2}\,\frac{a_1\,w_1^2 - a_2\,w_2^2}{w_2\,a_2 - w_1\,a_1}.$$

The experiments showed that ϕ increased as the period of the inducing current diminished. With the core consisting of a bundle of fine wires, the change of phase was so small as to be scarcely appreciable. It increased with the diameter of the bar. For a bar 17 millimetres diameter it was approximately $\frac{\pi}{2}$, and this was also the case for a bar 8 millimetres diameter but 1 metre long, so that it projected at both ends of the coil.

It may be noted that in determining the electro-magnetic potential the effect of the change of phase was not allowed for. In the two methods employed this correction would have opposite effects, which may account for some discrepancies in the results. Both methods, however, agree in showing that for periods of the inducing current from about $\frac{1}{50}$ to $\frac{1}{180}$ of a second the magnetic moment of the bars and wires up to a diameter of about 5 millimetres is independent of the period. For thicker bars the induced magnetism diminishes as the period diminishes, and the thicker the bar the more marked is the diminution.

It has been assumed that both the inducing and the induced currents follow the simple law of sines. If the expression for one current contained higher terms of Fourier's series, while the other consisted of the single term, it can be shown that the induced magnetism in the above method would appear less than it really is; for, to use an acoustical analogy, the effect of the fundamental tone only would be observed and not that of the overtones.

E. H.

On the Electrical Resistance of Glass at Low Temperatures.
By G. Foussereau.

(Journal de Physique, vol. ii., 1883, p. 254.)

As the resistances to be measured were exceedingly high the Author made use of the condenser method. The positive pole of a voltaic battery of from 3 to 100 elements was connected with the inside of a beaker of sulphuric acid; a test-tube made of the glass, whose specific resistance was sought, was also filled with sulphuric acid and placed within the beaker, so that the liquid stood at the same height within and without the test-tube. One plate of a condenser, of about a microfarad capacity, was coupled to the negative pole of the battery, and the other connected with the acid within the test-tube. The plates were also connected with the terminals of a Lipmann's capillary electrometer. The acid served the double purpose of forming the electrodes, and keeping the surface of the glass dry, but for temperatures above 80° it begins to evaporate and form a film over the surface, hence for such temperatures mercury was substituted. If C C′ be the capacities of the condenser and electrometer respectively, E the electromotive force of the pile, e the difference of potential between the condenser plates after a time θ, h be the height of the tube covered by the acid, and ρ_1 ρ_2 its inner and outer radius, then r the specific resistance is given by

$$r = \frac{2 \pi h \mathrm{E}}{(\mathrm{C} + \mathrm{C}^1)\, e \log \frac{\rho_1}{\rho_2}} \theta.$$

The capillary electrometer has a sensible capacity, the one used by the Author being about 0·24 microfarad. The effect of the test-tube arrangement, as itself a condenser, was eliminated by allowing an interval to elapse between the time of connecting the pile and the time from which θ is reckoned.

The following abbreviated Table gives the results of the experiments for Bohemian, ordinary, and crystal glass:

Temperature. °	Bohemian Glass. Density 2·431.	Ordinary Glass. Density 2·539.	Crystal Glass. Density 2·933.
−17	..	7,970·0	..
−15	330·0	6,330·0	..
− 5	109·0	1,730·0	..
0	59·0	990·0	..
10	18·6	284·0	..
20	6·62	91·0	..
30	2·20	27·4	..
40	0·811	8·46	..
45	0·509	4·34	6,650·0
50	0·299	2·39	3,420·0
60	..	0·784	988·0
70	..	..	288·0
80	..	..	98 0
90	..	..	39·6
100	..	..	16·6

The numbers give the specific resistance in millions of megohms. The results may be expressed by the empirical formulas:—

$$\log k = 3{\cdot}00507 - 0{\cdot}052664\,t + 0{\cdot}00000373\,t^2$$
$$\log k = 1{\cdot}78300 - 0{\cdot}049530\,t + 0{\cdot}0000711\,t^2$$
$$\log k = 7{\cdot}22370 - 0{\cdot}088014\,t + 0{\cdot}00028072\,t^2$$

for the ordinary, Bohemian, and crystal-glass respectively. The Author observed that tempering considerably diminished the resistance of glass.

E. H.

Influence of Magnetism upon Thermal Conductivity.

By J. TROWBRIDGE and C. B. PENROSE.

(Proceedings of the American Academy of Arts and Sciences, 1882–1883, p. 210.)

According to the experiments of Maggi the magnetic state of iron affects its thermal conductivity. Sir William Thomson has shown that transverse magnetization increases the electrical conductivity of iron, whereas longitudinal magnetization diminishes it, which, from the general analogy between the thermal and electrical conductivity of metals, would accord with Maggi's results. The Authors' investigations would appear to show that magnetization does not at all affect the thermal conductivity of iron.

The method employed was as follows: A bar of soft Norway iron 95 centimetres long was bent upon itself at a distance of 17 centimetres from one end. At the end of the bent part, and at the point of the bar opposite this end, were soldered two German-silver wires. The two thermo-electric junctions thus formed were about 0·4 centimetre apart, and were separate from each other by densely-packed asbestos. The arm was placed in a glass tube wrapped with asbestos cloth to shield it from any heating effect in the magnet coils, and placed between the magnetic poles producing a field of about 1760 C.G.S. units. The bar was heated about 19 centimetres from the thermo-electric junctions, consequently any heating effect from the coils would have an equal effect on the two junctions, while any change, due to the altered conductivity, of the flow of heat along the bar would affect the relative temperatures of the junctions. When the German-silver wires were connected with a low-resistance galvanometer, and the unheated bar placed either parallel or perpendicular to the axis of the magnet, there was no deflection. The bar was then heated, and the deflection watched until it became permanent, the magnetic field was then made and maintained for an hour, and in every case there was absolutely no change in the deflection beyond that due to the direct effect of the magnets, showing that the temperatures of the junctions remained the same.

E. H.

Measurement of the Striking Distance of the Electric Spark in different Mediums. By J. B. Baille.

(Annales de Chimie et de Physique, 1883, p. 181.)

The potential requisite to obtain the first spark at a given distance is much higher than for subsequent ones of a series, and higher for a medium enclosed in a glass vessel than for one enclosed in a metallic vessel; in air the potential required to produce a spark of given length diminishes rapidly with increased humidity.

The potential divided by the pressure to which the gas is subjected gives a value practically constant for the same distance between the electrodes.

The equation, $V\ (1 \times a\ t^2) =$ a constant, represents very nearly the effect of temperature, V being the potential, and a the coefficient of expansion of the gas in question, and t the temperature.

In different gases the spark is distinguished by its coloration, and the potential required as compared with air gives a nearly constant ratio for all distances. Thus for chlorine 0·85, for illuminating-gas 0·60, and for hydrogen 0·50, are the values determined by the Author. The experiments with carbonic acid and hydrochloric acid gases were attended with such difficulties, and the results so variable, due, perhaps, to decomposition and recombination of their molecular structure under the influence of the spark, that the values are omitted; the same remark applies to the experiments in various insulated liquids.

F. J.

Telephone-Exchanges in Switzerland. By T. du Moncel.

(La Lumière Électrique, vol. x., 1883, pp. 33–41.)

In Switzerland the telephonic lines are aerial, running above the houses, and supported every 100 metres on iron riders, which straddle the roof-ridges, and are generally mounted with six horizontal iron traverses, on which are screwed eight to ten small bell-shaped insulators of porcelain. By this system the riders simply rest on the ridge without any fastenings, and this easily admits of removals. The distance of 100 metres is not uniform; sometimes it is reduced to 30, or is prolonged to 300 metres. The riders are constructed of angle-iron, 5 or 6 centimetres in width, by 5 to 7 millimetres thickness, and the crosspieces for the insulators are of 4 to 5 centimetres T-iron, by 3, 5, to 7 millimetres thickness; the weight of the riders sometimes exceeds 500 kilograms, and the number of wires supported varies from forty-eight to sixty. That the tiles or slates may not be broken by the riders, the limbs rest on pads of tarred canvas packed with mineral wool. The riders are maintained vertical by ties of iron wire. The distance between the wires on the riders varies from 30 to 50 centimetres, according to the span, the latter figure corresponding to a span of 200 metres.

The wire adopted is cast steel, galvanised, of 2 millimetres diameter, supporting a tension of 400 to 450 kilograms, with a maximum of 2 per cent. elongation; but it has a resistance of 60–65 ohms a kilometre. Joints are made with very soft galvanised iron wire, 1 millimetre diameter, and they should not be more than 10 metres from the point of support. The maximum strain is 60 kilograms, owing to rigour of climate.

The insulators are small cylinders of porcelain, contracted at the middle, the bottom being hollowed and screwed, into which the support is fastened. Where there are no houses, poles are used, but the insulators are replaced by those of the ordinary telegraph form; and if the distance is great, the wire employed is the ordinary telegraph-line wire. The riders are furnished with lightning-conductors.

Gilliland's commutator is adopted in the central offices, and is on the "Jack-knife" principle; and the fall of the call-plate exhibits the number and completes the call-circuit. The transmitters are indifferently the Blake, Theiler, Ader, and Berliner. According to the Director-General, Mr. Rothen, these are equally effective and defective; the Blake will give the purest sounds, is easily put out of regulation, but needs only a single Leclanché element; the Theiler is less delicate; does not sputter as easily as the preceding, but the reproduction of speech is less clear and strong, and needs 2 to 3 Leclanché elements; the Ader is feeble, but distinct, and sputters the least; it needs four Leclanché elements, two by two; the Berliner is slightly more indistinct than the Blake, but is less delicate and needs one cell. Calls are made by battery, and by induction-currents, but only the town of Basle employs the former method, in which six cells are used. The magneto-generators furnish currents of 45 volts, and are of 500 ohms resistance. The other arrangements are those commonly in use.

P. H.

On the Relation of certain Electro-magnetic Phenomena suggested by the Mechanical Theory of Heat. By ANTON WASSMUTH.

(Sitzungsberichte der kaiserlichen Akademie der Wissenschaften, vol. lxxxvii., 1883, p. 82.)

The Author in this Paper further extends his previous investigations on the application of the laws of thermo-dynamics to the phenomenon of magnetisation. Adopting the notation used in the previous Papers,[1] let a quantity of heat $d\ Q_1$, measured in mechanical units, be communicated to a mass of iron of volume v and

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[1] Minutes of Proceedings Inst. C.E., vol. lxxi., p. 517; and vol. lxxii., p. 417.

under pressure p. Then if $d\,\pi$ is the increase in internal energy, by the first law of thermo-dynamics,

$$d\,Q_1 = d\pi + p\,d\,v.$$

If the iron be subjected to a magnetising force k, and $d\mu$ be the change in magnetic moment, this equation becomes—

$$d\,Q_2 = d\pi + p\,d\,v - k\,d\,\mu.$$

Here $p\,d\,v$ has the same value as before, or differs only by a quantity of the second order. Hence

$$d\,Q_2 - d\,Q_1 = -\,k\,d\,\mu;$$

and, since by the second law of thermo-dynamics $\frac{d\,Q_2}{T}$ and $\frac{d\,Q_1}{T}$ are perfect differentials, so also is $\frac{k\,d\,\mu}{T}$, *i.e.* the work done in magnetisation is proportional to the absolute temperature.

Now assume $\frac{k\,d\,\mu}{T}$ to be a perfect differential of two independent variables y and z common to both states, then—

$$\frac{d}{d\,z}\left(\frac{k}{T}\frac{d\,\mu}{d\,y}\right) = \frac{d}{d\,y}\left(\frac{k}{T}\frac{d\mu}{d\,z}\right).$$

If y be put equal to T, this equation when expanded becomes—

$$\frac{d\,k}{d\,T}\,\frac{d\,\mu}{d\,z} - \frac{dk}{d\,z}\cdot\frac{d\,\mu}{dT} = \frac{k}{T}\,\frac{d\,\mu}{d\,z}.$$

The differentials $\frac{d\,\mu}{d\,T}$ and $\frac{d\,k}{d\,T}$ involved in this equation are magnitudes either already known or easily evaluated. The former $\left(\frac{d\,\mu}{d\,T}\right)_z$, expressing the change of magnetic moment with the temperature, when z is constant, cannot differ much from $\left(\frac{d\,\mu}{d\,T}\right)_k$, and this was shown, in the Author's previous researches, to be given by the equation—

$$\left(\frac{d\,\mu}{d\,T}\right)_k = C\,\frac{\mu}{k} - B\,\mu,$$

where C and B are certain constants.

Also $$\frac{d\,T}{d\,k} = -\,\frac{T}{M\,C_2}\left(\frac{d\,\mu}{d\,T}\right)_k,$$

where C_2 is the specific heat of magnetised iron, and M is the mass, which may be taken as unity. Hence $\left(\frac{d\,\mu}{d\,z}\right)_T$ and $\left(\frac{d\,k}{d\,z}\right)_T$ are connected by a known relation, from which particular cases may be deduced.

Returning to the first equation

$$\left(\frac{d\,Q_2}{d\,T}\right)_z - \left(\frac{d\,Q_1}{d\,T}\right)_z = -\,k\left(\frac{d\,\mu}{d\,T}\right)_z,$$

or

$$C_2 - C_1 = -\,k\left(\frac{d\,\mu}{d\,T}\right)_z$$

where C_2 C_1 are the specific heats in the magnetised and unmagnetised states respectively, z being constant. This relation may be also simply proved by applying the first law of thermo-dynamics to a cycle of changes, through which the iron may be supposed to pass. Again assuming $\left(\frac{d\,\mu}{d\,T}\right)_z = \left(\frac{d\,\mu}{d\,T}\right)_k$ then—

$$\frac{d\,\mu}{d\,T} = -\,\frac{C_2 - C_1}{k}$$

$$\frac{d\,k}{d\,T} = \frac{k}{T}\,\frac{C_2}{C_2 - C_1},$$

and hence

$$\frac{d\,k}{d\,z} = -\,\frac{C_1}{(C_2 - C_1)^2}\,\frac{k^2}{T}\,\frac{d\,\mu}{d\,z}.$$

Since the first two factors of the right-hand member are always positive, $\frac{d\,k}{d\,z}$ and $\frac{d\,\mu}{d\,z}$ are so related that if one increases with increasing magnetisation, the other diminishes, and *vice versâ*.

The Author then applies the foregoing to the case of an iron bar of length l, subject to a magnetising force k, stretched by a force P in the direction of its axis. To determine the cooling effect of stretching—

$$d\,Q_2 = d\,U - P\,d\,l - k\,d\,\mu,$$

and

$$\frac{d\,Q_2}{T} = d\,S_2.$$

Hence taking T and P as independent variables

$$\frac{1}{T}\,\frac{d\,Q_2}{d\,P} = \frac{d\,l}{d\,T} - \frac{d\,k}{d\,T}\,\frac{d\,\mu}{d\,P} + \frac{d\,k}{d\,P}\cdot\frac{d\,\mu}{d\,T};$$

but putting P for z

$$\frac{d\,k}{d\,T}\,\frac{d\,\mu}{d\,P} - \frac{d\,k}{d\,P}\cdot\frac{d\,\mu}{d\,T} = \frac{k}{T}\,\frac{d\,\mu}{d\,P};$$

Therefore

$$\frac{1}{T}\,\frac{d\,Q_2}{d\,P} = \frac{d\,l}{d\,T} - \frac{k}{T}\,\frac{d\,\mu}{d\,P}.$$

If the iron receive no heat,

$$d\,Q_2 = \frac{d\,Q_2}{d\,T}\,d\,T + \frac{d\,Q_2}{d\,P}\,d\,P = C_2\,d\,T + T\left(\frac{d\,l}{d\,T} - \frac{k}{T}\frac{d\,\mu}{d\,P}\right)d\,P = 0,$$

where C_2 is the specific heat of magnetised iron for a constant tension. Hence the change of temperature is given by

$$\frac{d\,T}{d\,P} = -\frac{T}{C_2}\left(\frac{d\,l}{d\,T} - \frac{k}{T}\frac{d\,\mu}{d\,P}\right).$$

Since $\frac{T}{C_2}\frac{d\,l}{d\,T}$ represents approximately the cooling of unmagnetised iron by extension, it appears from the equation that this is diminished by $\frac{k}{C_2\,T}\frac{d\,\mu}{d\,P}$. In his previous investigations the Author has shown that for weak magnetisations $\frac{d\,\mu}{d\,P}$ is positive; hence in this case the cooling effect of stretching is less when the iron is magnetised than when not magnetised. For very strong magnetisations $\frac{d\,\mu}{d\,P}$ is negative, and hence the converse holds in this case. This is probably also the case for the permanent magnetisation of steel, since its general characteristics are similar to those of strongly magnetised soft iron. The experiment was tried for the Author by Mr. Haga with steel wire, and he found that the cooling effect was about 6 per cent. greater for the steel when magnetised.

Considering next the magnetic effects of torsion, two cases are to be distinguished; first, where the torsion is permanent; secondly, where the bar is torsionally strained by a tangential stress. Let N be the torsional force, and take it as an independent variable in place of P; then $\frac{d\,\mu}{d\,N}$ and $\frac{d\,k}{d\,N}$ are of contrary sign. It is known that if an iron bar is twisted, through which a current is passing, the temporary magnetism is increased, *i.e.* $\frac{d\,\mu}{d\,N}$ is positive. Hence $\frac{d\,k}{d\,N}$ should be negative, *i.e.* the torsion should diminish the magnetising force. This appears in the known phenomenon that the torsion of a twisted bar diminishes, when it is magnetised. It is also known that this diminution in the torsion attains a maximum as the magnetising force is increased. This appears from the analysis, since $\frac{d\,\mu}{d\,T}$ when the magnetising force is weak is represented by the first term only, viz. $C\frac{\mu}{k}$; $\frac{d\,\mu}{d\,N}$, which follows in general the same laws, will be expressed by a term $F\frac{\mu}{k}$. Hence

$$\frac{d\,k}{d\,N} = -\frac{H}{\frac{\mu}{k}}$$

where H is a positive constant, and $\frac{\mu}{k}$ is the coefficient of magnetisation. Since the latter is known to attain a maximum and then diminish, $\frac{d\,N}{d\,k}$ must also have a maximum. Now the permanent magnetism of steel bars is diminished by torsion, and the coefficient of the effect diminishes as the torsion increases. This is in agreement with the assumption that $\frac{d\,\mu}{d\,N}$ is similar in form to $\frac{d\,\mu}{d\,T}$; so that

$$\frac{d\,\mu}{d\,N} = F\frac{\mu}{k} - G\,\mu.$$

When the magnetising force is weak the first term is the most important, but when very strong this term vanishes, and

$$\mu = e^{-G\,N}$$

whence

$$\frac{d\,\mu}{d\,N} = -\frac{G}{e^{G\,N}}.$$

Where the magnetisation is therefore about its maximum torsion must produce a decrease in the magnetic moment, and this coefficient of the decrease must be smaller, when the torsion is greater.

Again, since $\frac{d\,k}{d\,N}$ is of opposite sign to $\frac{d\,\mu}{d\,N}$, $\frac{d\,k}{d\,N}$ must be positive, which agrees with the observation that a magnet through which a current is passed in the direction of its axis, is twisted.

If the torsion is produced by a tangential force an exactly opposite law obtains, which may be stated thus: If a wire is magnetised while subjected to a twisting force, the torsion is increased when the magnetisation is weak, and diminished when strong.

Finally, the Author points out that the fact that $\frac{d\,\mu}{d\,z}$ and $\frac{d\,k}{d\,z}$ are of contrary sign is capable of a very simple explanation. When the magnetising force is small the coercive force and free magnetism are the principal considerations, and these diminish as z increases, and therefore $\frac{d\,\mu}{d\,z}$ is positive, since their effect is opposed to the magnetising force. But on the other hand, with an increasing magnetising force a motion of the molecules takes place, which is increased as z increases, and hence $\frac{d\,k}{d\,z}$ is negative. If the magnetisation is very strong, the coercive force loses its influence. If iron so magnetised be heated or stretched or twisted, the molecules more rapidly assume their mean positions, and consequently the magnetic moment is smaller, and therefore $\frac{d\mu}{dz}$ is negative, while $\frac{dk}{dz}$ is positive, since both z and k tend to increase the molecular disturbance.

E. H.

The Unit of Light. By Dr. Hugo Krüss.

(Journal für Gasbeleuchtung, April 1883, p. 213.)

The standard candles used in different places for photometric purposes may agree so well one with another that they constantly represent the same illuminating value, nevertheless each individual candle leaves much to be desired in regard to the constancy of its light; and the Carcel lamp, the standard light in France, appears to give little better results. With candles and oil-burners it is impossible to maintain a uniform consumption of the material. On this account it has been several times proposed to use bodies of fixed dimensions, which should be rendered incandescent by an electric current as units of light. On account of the necessity of providing a uniform current of a certain strength, and, in fact, because of the introduction of electricity into the question, such propositions have not received much attention from gas-manufacturers.

The Author is of opinion that illuminating gas itself is the best material to utilize for the construction of a light unit. The way to do this has been pointed out by Mr. Giroud.

The absolute amount of light given by the standard light-unit is a matter of comparative indifference. Giroud fixed his unit at one-tenth of a Carcel lamp. His unit is a one-hole gas-burner, having an orifice 1 millimetre in diameter, and yielding a flame 67·5 millimetres in height.

To maintain the height of a gas-flame constant for any considerable period of time, the volume of gas consumed must also be kept constant. Giroud used for this purpose his photo-rheometer, a more than usually sensitive and perfect form of governor, the principle of which is that the gas passes through a small hole in the top of a bell floating in glycerine, and the velocity at which it passes depends neither upon the pressure of the gas above nor upon that below the bell, but upon the difference between them. This difference of pressure is equal to the power required to maintain the bell in a position of equilibrium, and is always the same. A cone-valve is attached to the bell, and when the pressure of the gas in the main-pipe increases, the bell rises and assumes a fresh position, at which the quantity of gas passing the valve is sufficient to balance it.

In order to allow the gas to burn at different rates of consumption, the photo-rheometer has a by-pass cock at the side, which permits a certain quantity of gas being passed from the inner to the outer side of the bell without passing through the hole in the bell.

In using the rheometer of Giroud to regulate a jet-photometer, it matters not what difference there may be in the diameter of the orifice of the burner. When two burners, one having a hole 1 millimetre in diameter, and the other a hole 1·5 millimetre in diameter, are successively regulated by the same rheometer, the flames reach to exactly the same height, and in each the consumption of gas is exactly the same. The pressure only in the connecting-pipe above the rheometer is altered; it is less with the wider burner than with the smaller one. When a pressure regulator is used the effect is just the reverse. Then the pressure in the pipe supplying the burners remains constant, and the height of the flames, as well as the consumption of gas, vary.

For use as photometric standards it is necessary that the burners have holes of uniform size, or nearly so. Giroud compared the illuminating power of two such burners as described above, and found that the light from the burner having a hole of 1 millimetre diameter was 15 per cent. less than that of the burner having a hole 1½ millimetre in diameter. This difference is probably due to the difference of pressure at which the two flames burned. In constructing a standard-unit burner, therefore, care would have to be bestowed upon the diameter of the hole in the burners; but a difference of $\frac{1}{20}$th of a millimetre would only make a difference of 1 per cent. in the illuminating power.

The effect of variation in the quality of the gas used was investigated by Giroud in the following manner:—Two one-hole burners, having holes 1 millimetre diameter, were fixed one at each end of a Bunsen photometer. Both burners were fed by the same stream of gas, which was divided into two parts before arriving at the burners, and on each burner was fixed a rheometer for regulating the consumption of gas to 30 litres per hour. One of the rheometers was fitted with the side-cock already referred to, by which the consumption could be increased as desired. To the pipe conveying the gas to this rheometer another pipe from a gas-holder filled with air was attached, the air in the holder being under heavier pressure than that of the gas in the supply-pipe. Air could therefore be forced into the gas-pipe and mixed with the gas supplied to one burner, while pure gas only passed to the other. After proving that the two burners, when supplied with gas, only gave an equal illuminating power, Giroud then allowed air to mix with the gas passing to the one burner, upon which the height of the flame was immediately reduced and the illuminating-power diminished. He then gradually opened the regulating-cock at the side of the rheometer until the flame, owing to the increased consumption, had risen to the original height. The two flames were then found to be again of equal illuminating power. The rheometer gives a constant volume only when the constitution of the gas remains unchanged. If the specific gravity of the gas vary, so will the rate of delivery, and the rate of delivery is in inverse proportion to the square root of the specific gravity.

In using the standard light-unit recommended by Giroud, it does not matter what the specific gravity of the gas may be, provided the height of the flame be maintained at a constant lèvel, which can be accomplished with ease by means of the photo-rheometer having the by-pass cock before referred to. The standard recommended by Giroud is a one-hole burner, having a hole of 1 millimetre diameter, and burning a flame 67·5 millimetres in height. This flame possesses an illuminating power of one-tenth of a Carcel lamp.[1]

For measuring the illuminating power of large lights a more powerful standard is required. In such cases Giroud recommends the employment of burners having ten and fifty times the illuminating power of the proposed unit. These burners are to be connected on the same stand with the unit standard, with which they are to be first compared, and by which they are to be adjusted; a small photometric screen and disk being fixed at the proper proportional distance between the two burners.

G. E. S.

Comparative Experiments with Standard Photometric Candles.

By Dr. Hugo Krüss.

(Journal für Gasbeleuchtung, August 1883, pp. 511, 552.)

In the year 1882 the German Association of Gas and Water Engineers decided to institute experiments with the standard candles used in photometric observations. The principal reason for these experiments being that for fourteen years the Candles-Commission of the Association had been working in the matter of the improvement of the Association standard candles, yet complaints of their imperfection and unreliability had been made, notably by Professor Rüdorff.

The Author was requested by the Commission to undertake experiments, according to the instructions of the Commission, with three different kinds of candles, viz.:—

1. The Munich Stearine candles, the dimensions of which are: length, 315 millimetres; diameter at top, 20·5 millimetres; at bottom, 23 millimetres. Average weight, 108·9 grams.
2. The German Association Paraffin candles: length, 314 millimetres; diameter, 20 millimetres. Average weight, 83·6 grams.
3. The English Sperm candles (London Standard Sperm candles):

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[1] The Carcel lamp being equal to 9½ sperm candles the standard unit woul give a light equal to 0·95 of a candle, and 16-candle gas would appear a 16·73 candles.—G. E. S.

length, 252 millimetres; diameter at top, 20 millimetres; at bottom, 22·5 millimetres. Average weight, 75·7 grams.

In using the candles, the German custom is to estimate their light-value by the height of the flame, and the height fixed for the three different kinds of candles above-mentioned are, for

	Millimetres.
The Munich stearine candles	52·0
The Association paraffin candles . . .	50·0
The English sperm candles	44·5

The usual method of procedure is for the operator to trim the wick of the candle, which brings the flame below the standard height; then to wait until it has burnt up to the proper height, take a few observations, and as soon as the flame has risen too high, trim again. The Author objects to this plan, and prefers to wait until the flame has returned to its normal position before making the observations. The standard height, however, must be one at which the candle will naturally burn regularly for a considerable period. The height of 44·5 millimetres fixed for the English sperm candle does not correspond with this condition.

A set of experiments was made, first of all to determine the height of flame with which the candles most frequently burn.

The variations in the height of the flame amounted, in the case of the Stearine candles, to 11 millimetres; with the paraffin candles, to 16 millimetres; and with the sperm candles to 8 millimetres. These experiments showed that the flame of the Stearine candles was most frequently 54 to 56 millimetres in height, and very seldom 52 millimetres; that of the paraffin candles varied from 52 to 54, instead of 50 millimetres; and the usual height of the sperm candles was 47 to 48, instead of 44 millimetres.

The mean divergence from the standard height amounted, for the Stearine and paraffin candles, to ± 1·98 millimetre, and for the sperm candles to ± 1·57 millimetre.

The general result of these experiments showed the sperm candle to be more constant than the two descriptions of German candles, both in regard to the variations in the height of the flame in each individual candle, and also in regard to the variations between different candles of the same material.

They also showed that without trimming the wick there is great difficulty in maintaining a standard height. The average height of flame, which may be taken as the natural height of burning, was found to be 54 millimetres for the Stearine, 53·51 for the paraffin, and 47·7 for the sperm candles, and the variations in the height, worked out in percentages, come to 20 per cent. for the Stearine, 30 per cent. for the paraffin, and 17 per cent. for the sperm candles.

To determine the variations in the amount of light afforded by the different candles, the Author employed a photo-rheometer, by Giroud, which he previously subjected to a very severe test, and found to be absolutely constant in the amount of light yielded with a given height of flame.

The results of these experiments were as follows:—

MEAN VARIATION in ILLUMINATING POWER.

	With Flame of 44·5 Millimetres.	With Flame of Standard Height.
	Per cent.	Per cent.
Stearine candles	5·6	5·4
Paraffin "	4·3	7·7
Sperm "	3·0	3·0

In these experiments the sperm candles showed the least variation. The Author expresses the opinion that the English standard sperm candle is equally reliable with the French Carcel lamp, as the latter is admitted to vary from 2 to 3 per cent.

As regards the actual amount of light given by the different candles, the experimenter sets the Stearine candles at 100, and finds that at 44·5 millimetres height of flame the paraffin candles give a light equal to 106·4, and the sperm candles a light equal to 108·4. At the normal standard height of flame the paraffin candles equal 97·6, and the sperm candles 85·8.

The light-value of the sperm candles is, according to these experiments, such that 11·2 candles are equal to the Carcel lamp, whereas most experimenters have found 9·6 candles equal one Carcel burner. The height of flame at which the candles were tested was, however, not equal to the consumption of 120 grains of sperm per hour, which is the standard consumption in English photometry.

The Author also made experiments to ascertain the melting-point of the different materials of which the candles were composed, and found the Stearine candles to have an average melting-point of 53·99° Centigrade; the paraffin candles, 53·75°, and the sperm candles 43·66°. He also remarks that the different sperm candles tested agreed more closely with one another in this respect than the two other descriptions of candles.

G. E. S.

On the Photometric Comparison of Lights of Different Colours.

By J. MACÉ DE LÉPINAY and W. NICATI.

(Compte-rendu de l'Association française pour l'avancement des sciences, 1882; p. 223.)

It is well known that most methods of photometry are not applicable for the comparison of sources of light of different colours. Two methods might appear free from this objection. The first depends upon the fact that the details of objects are within certain limits more readily distinguished when the quantity of light is increased. Two lights may be regarded as equal, if when they are employed to illuminate colourless objects on a white ground, the visual definition is the same. The second method assumes that two quantities of light are equal, when under the same conditions they equally illuminate a white surface, as for instance in Rumford's photometer. The practicability of this method is much increased, if the surfaces employed are very small, since the eye then appreciates the coloration with much greater difficulty. The Author's experiments were directed to the question, whether these two methods would give the same results, when applied to lights of different colours.

Consider a spectrum in which the maximum visual definition which occurs in the yellow is represented by V. In other regions, for example in the red, the visual definition will have a smaller value, and the intensity of the white light of the source producing the spectrum, must be increased to attain the visual definition V. The number which represents the proportionate increase of white light, to obtain the same definition as that of the maximum region, may be called the coefficient of equal visual definition. Similarly, suppose the illumination of a surface has a certain maximum value, defined by a Carcel candle, in a particular portion of the spectrum, then the ratio in which the white light of the source must be increased to bring the illumination up to this maximum value for other portions of the spectrum, may be called the coefficient of equal brightness. If the shadow thrown on the illuminated surface be one millimetre broad, and measurements be made with the height, eight millimetres and four millimetres respectively, it is found that the coefficient of equal brightness is greater in the latter case in the blue, and smaller in the red. This variation continues down to a height of two millimetres, after which no change occurs, if the distance of the eye be kept constant, and such as to produce an image on the retina not greater than 0·2 millimetre in diameter. In determining the coefficients of equal visual definition, the object viewed had a length of 5 millimetres, and the eye was placed at a distance of 1·10 metre, producing an image on the retina of about 0·075 millimetre. The following are the results of the comparative experiments by the two methods: The coefficients of visual definition are referred to V = 0·33, or a quantity of light equal to 0·0067 of a Carcel candle at a distance of one metre. The coefficients of equal brightness are also referred to 0·0067 of a Carcel.

$10^5 \lambda$.	Coefficients of equal visual definition.	Coefficients of equal brightness.
6·702	41·91	44·33
6·249	2·562	3·405
5·895	1·271	1·315
5·607	1·004	1·015
5·370	2·160	1·100
5·169	2·281	1·933
4·996	11·64	5·196
4·845	35·64	11·40
4·711	88·88	18·80
4·590	185·6	35·94
4·486	281·3	49·63
4·389	..	71·02
4·301	..	116·1

The values obtained from the two methods are thus in tolerably close accordance for rays less refrangible than the blue end of the yellow, but completely different for the more refrangible rays. It would hence appear that in public lighting, where distinctness is the principal consideration, an intense gas-flame or incandescence-lamps are preferable to arc lighting.

E. H.

On Hall's Phenomenon in Liquids. By Anton Roiti.

(Exner's Repertorium der Physik, vol. xix., 1883, p. 347.)

Hall has shown that when a current is passed through a thin plate of metal, there is a transverse electromotive force induced in the plate, if it is placed with its plane perpendicular to the lines of force of a magnetic field. This is the phenomenon suggested as possible by Maxwell, and expressed by the assumption of a "rotatory coefficient" in the equations of conduction. Hall has determined this coefficient for various metals. The Author first experimented with a sheet of silver electrolytically deposited on glass, and in general verified Hall's results. The experiment was then tried in a different way. The main current was passed through a silver wire, A B, 0·03 millimetre in diameter, and about 4 centimetres long, held by two stout copper wires. At right angles to this was a second similar silver wire, C D, forming a cross with the first. This second wire was stretched by two suspended weights, and had stout copper wires similarly attached to it. The plane of the wires was at right angles to the lines of magnetic force, their point of intersection being in the axis of the electro-magnets. The copper terminals of C D were connected with an exceedingly sensitive galvanometer. It was found that if the tension of the wire was considerable, no effect whatever could be observed when the direction of the field was reversed, even with a primary current produced by six Daniell's. This shows that the supposition of a direct effect upon the current is not admissible, and that the phenomenon really depends upon a change in the specific resistance, in the manner considered by Maxwell.

In experimenting on liquids, the Author found that the polarization introduced considerable difficulties, but he concludes from experiments with sulphate of zinc solution, that if the concentration of the solution is less than that of maximum electrical conductivity (specific gravity 1·286), the electro-dynamic action produces an increase in the conductivity of the liquid in the direction of C D, and conversely if the concentration is greater than that of maximum conductivity.

E. H.

On the Distribution of Potential in Liquid Masses.

By A. CHERVET.

(Comptes rendus de l'Académie des Sciences, vol. xcvii., 1883, p. 709.)

The Author first considers the case of a rectangular plate of infinite length, and gives the formula for the point corresponding to the potential in terms of the ordinates. But the second case is the more general, and is that of a liquid mass limited by two vertical and parallel planes. The two electrodes, $+ V_0$ and $- V_0$, are situated on a horizontal line perpendicular to the two vertical surfaces, at the intersection of this line with each of the two surfaces; their radius a is very small, relatively to the thickness π of the plate. Let r_0 be the distance of a point P from the positive electrode; r_1 its distance from the negative electrode; $r_2\, r_3\, r_4$ . . . . the distances of the point P from points situated on the line of the electrodes, at the distances $2\,\pi$, $3\,\pi$, $4\,\pi$ from the positive electrode, on the side of the negative electrode; $r'_1\, r'_2\, r'_3$, the distances of the point P from points situated on the other side of this same line, at distances π, $2\,\pi$, $3\,\pi$, from this positive electrode. The potential at the point P will be given by the relation

$$\frac{V}{V_0} = \frac{\left(\frac{1}{r_0} - \frac{1}{r_1}\right) + \left(\frac{1}{r_2} - \frac{1}{r'_1}\right) + \left(\frac{1}{r'_2} - \frac{1}{r_3}\right) + \left(\frac{1}{r_4} - \frac{1}{r'_3}\right) + \dots}{\frac{1}{a} - 0{\cdot}441}$$

The constant $0{\cdot}441 = \frac{2\,.\,L\,.\,2}{\pi}$.

By means of the capillary electrometer, the Author has directly measured the potentials at different points of a similar liquid mass, and the accordance with the calculated potential has been found satisfactory.

P. H.

The Coefficient of Viscosity of Air.

By W. BRAUN and A. KURZ.

(Exner's Repertorium der Physik, vol. xix., 1883, p. 343.)

Also by A. KURZ.

(Exner's Repertorium der Physik, vol. xix., 1883, p. 605.)

I. In the deduction of the coefficient of viscosity of air from the Authors' former experiments[1] on the oscillations of a hollow ball there was an error which completely invalidates the results. It

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[1] Minutes of Proceedings Inst. C.E., vol. lxxi., 1882-1883, p. 523.

was assumed that the friction of the air within the ball had the same effect as that of the air without, and that this would be represented in the equation by writing $2k$ for k, k being the coefficient of viscosity. The value of k was therefore calculated from the equation

$$\delta = \frac{2\pi R^4}{3K}\sqrt{2\pi k \mu T},$$

where δ is the logarithmic decrement of the damping of the oscillations, R the outer radius of the ball, K the moment of its inertia about the axis of oscillation, μ the density of the air, and T the period. The Author has since repeated the experiments with a hollow globe, made in two halves so that the inner radius could be measured. The equatorial radius was 23·93 centimetres, and the polar radius 23·20 centimetres, the thickness varying from 4½ to 7 centimetres. The correct expression for the logarithmic decrement of damping is then

$$\delta = \frac{2\pi(R^4 + r^4)}{3K}\sqrt{2\pi k \mu T},$$

where R and r are the outer and inner radii respectively. The limiting values of k obtained from the observations were 0·000184 and 0·000137.

II. Meyer has determined the coefficient of viscosity of air, by observations on the damping of a disk oscillating about an axis perpendicular to its plane. The Author has repeated the observations, and finds for air at a temperature of 17° Centigrade, 0·000157 as the most probable value of k.

E. H.

INDEX

TO THE

MINUTES OF PROCEEDINGS,

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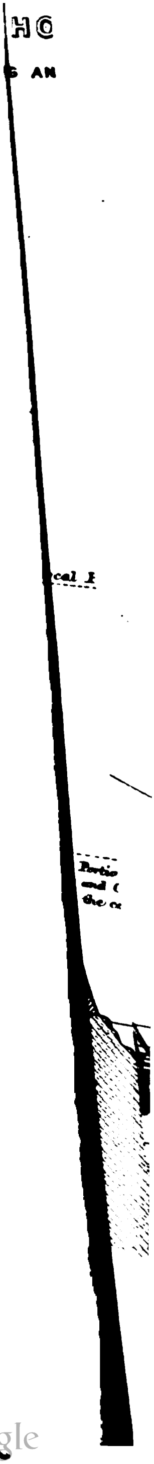

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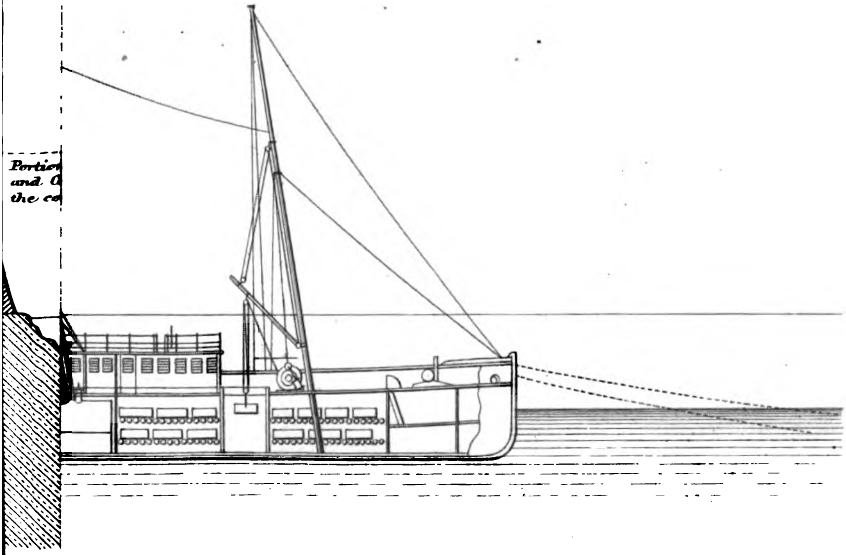

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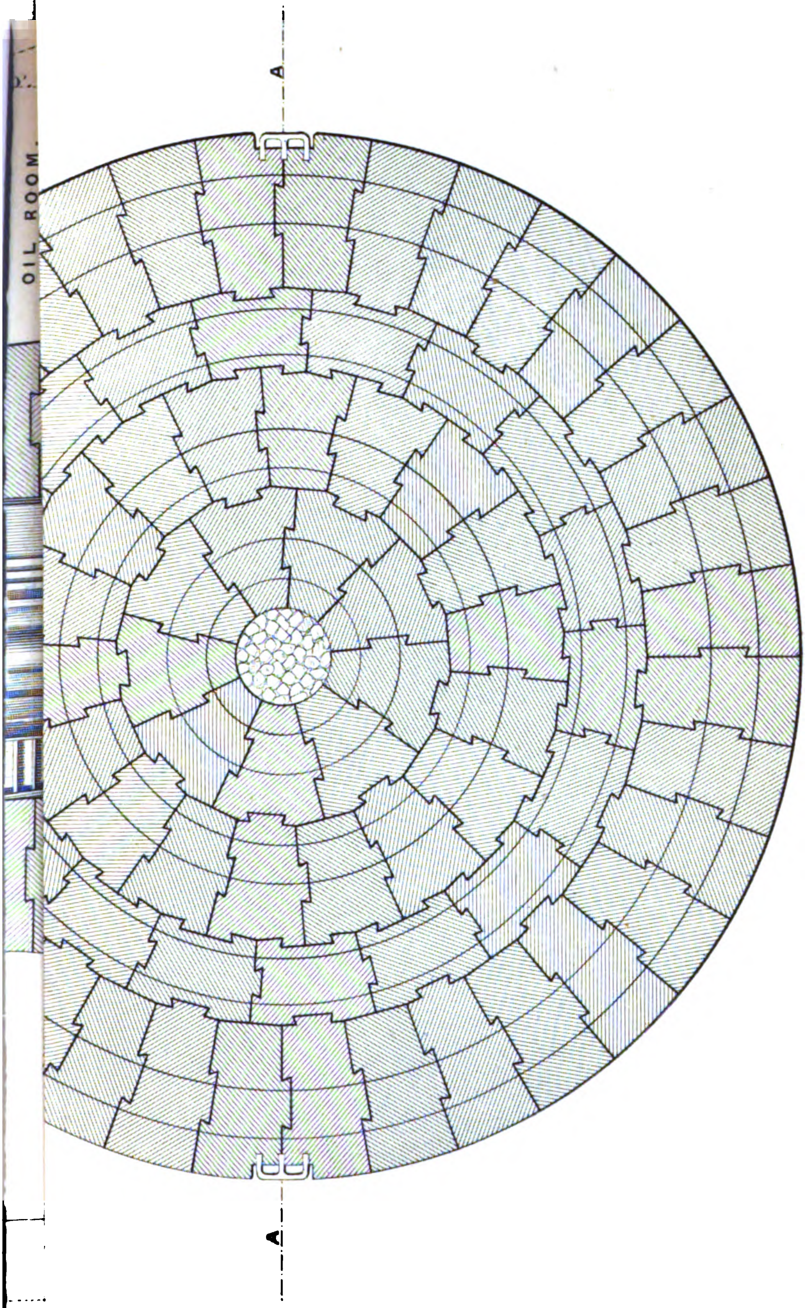
THOS KELL & SON. LITH. 40. KING ST COVENT GARDEN.

PLATE 2.



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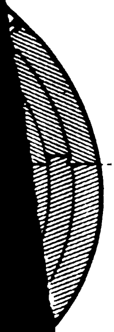
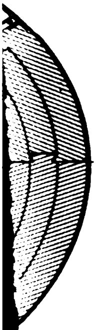
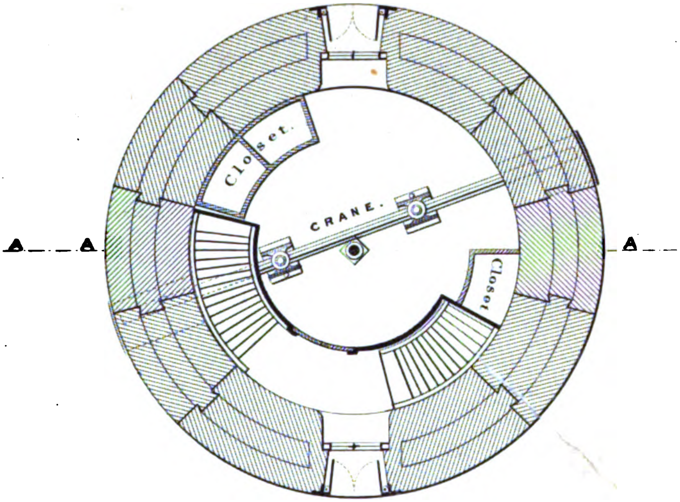
THOS KELL & SON. LITH. 40, KING ST COVENT GARDEN.







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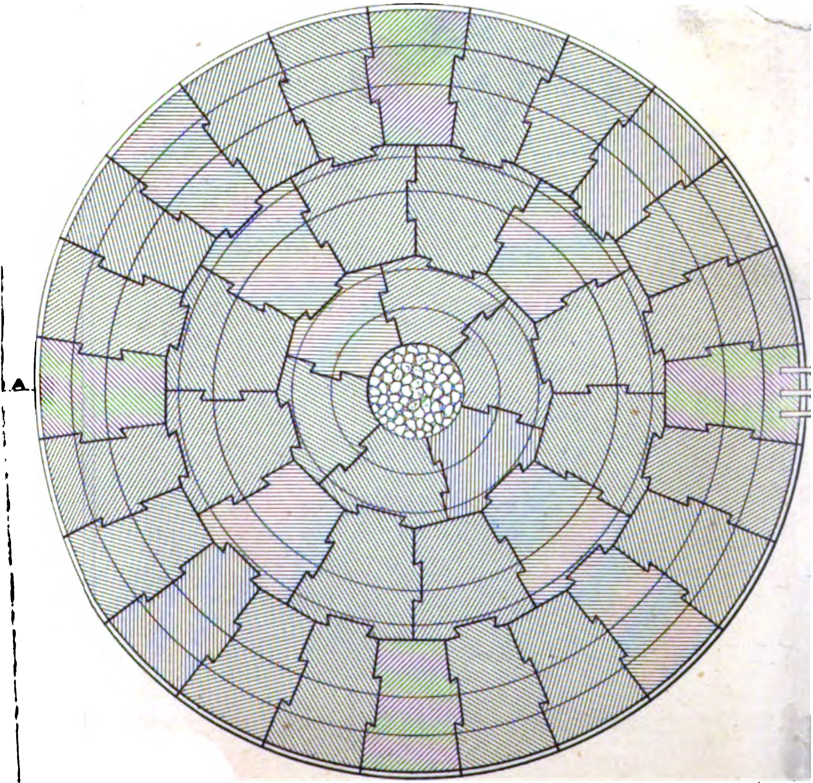

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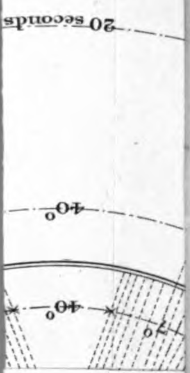

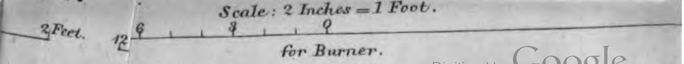

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Vol. LXXV. Session 1883-84. Part I.

THOS KELL & SON, LIT

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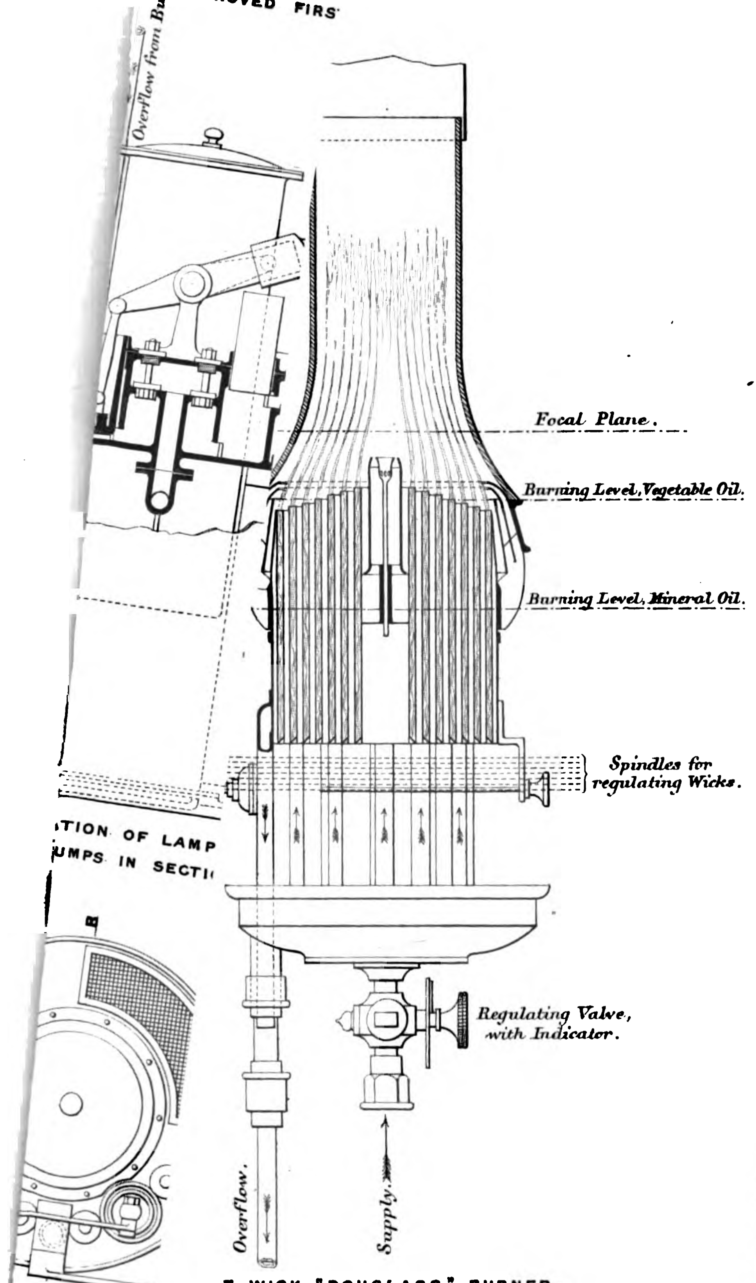

7 WICK "DOUGLASS" BURNER.

Scale : 2 Inches = 1 Foot.

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THOS KELL & SON, LITH. LON

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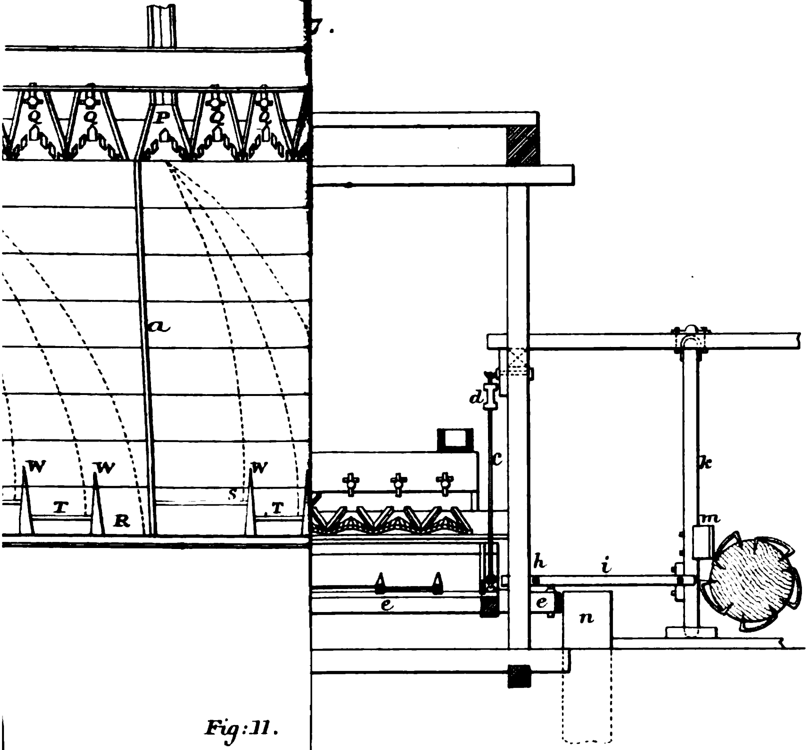

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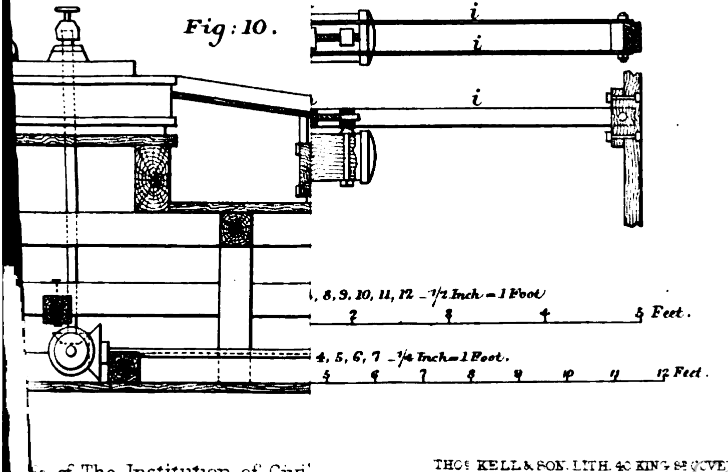

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THOS KELL & SON. LITH. 40 KING ST COVENT GARDEN.

TREAMS.

RIVERS, NEW SOUTH WALES.

Session 1883-84. Part I.

THOS KELL & SON, LITH.